7/1/00-3166

FINAL

SAMPLE STRATEGY PLAN
BACKGROUND STUDY
MCB CAMP LEJEUNE, NORTH CAROLINA

CONTRACT TASK ORDER 0371

JULY, 2000

Prepared for:

DEPARTMENT OF THE NAVY
ATLANTIC DIVISION
NAVAL FACILITIES
ENGINEERING COMMAND
Norfolk, Virginia

Under the:

LANTDIV CLEAN Program
Contract N62470-89-D-4814

Prepared by:

BAKER ENVIRONMENTAL, INC.
Coraopolis, Pennsylvania

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

TABLE OF CONTENTS
(Continued)

LIST OF FIGURES (continued)

LIST OF APPENDICES

LIST OF ACRONYMS AND ABBREVIATIONS

AOC	Areas of Concern
ASTM	American Society of Testing and Materials
Baker	Baker Environmental, Inc.
bgs	Below Ground Surface
CLEAN	Comprehensive Long-Term Environmental Action Navy Program
CLP	Contract Laboratory Program
CTO	Contract Task Order
DoN	Department of the Navy
f_{oc}	fraction of organic carbon
FSAP	Field Sampling and Analysis Plan
GSRA	Great Sandy Run Area
HASP	Health and Safety Plan
IDW	Investigation Derived Waste
IR	Installation Restoration
K_d	Partition Coefficient
LANTDIV	Atlantic Division, Naval Facilities Engineering Command
MCB	Marine Corps Base
msl	Mean Sea Level
NCDENR	North Carolina Department of Environment and Natural Resources
NFA	No Further Action
OEPA	Ohio Environmental Protection Agency
QAPP	Quality Assurance Project Plan
RBC	Risk Based Concentration
RCRA	Resource Conservation and Recovery Act
RFA	RCRA Facility Assessment
RFI	RCRA Facility Investigation
RI	Remedial Investigation
SSP	Sample Strategy Plan
SWMU	Solid Waste Management Unit
TAL	Target Analyte List
TCLP	Toxic Compound Leaching Procedure

LIST OF ACRONYMS AND ABBREVIATIONS
(Continued)

USEPA	United States Environmental Protection Agency
UST	Underground Storage Tank
WAR	Water and Air Research, Inc.

1.0 INTRODUCTION

This document presents the Background Study Sample Strategy Plan (SSP) prepared for Marine Corps Base (MCB), Camp Lejeune, North Carolina. It has been prepared by Baker Environmental, Inc. (Baker) under Contract Task Order (CTO) 0371 of the Department of the Navy's (DoN's) Comprehensive Long-Term Environmental Action Navy (CLEAN) Program.

Analytical results from soil samples collected during the Phase I confirmatory sampling were compared to USEPA Region III Residential Risk Based Concentrations (RBCs), NC DENR Method I Category S-2 Target Concentrations, NC DENR Method I Category S-3:G-1 Target Concentrations (soil to groundwater pathway), and base background for inorganics. Based on detected inorganics and their concentrations, specifically arsenic, cadmium, lead and mercury, NC DENR suggested that the comparison criteria/standards used for the evaluation of inorganics may not have been entirely appropriate. This suggestion was based on two main points of contention. The data gathered at MCB, Camp Lejeune during several Remedial Investigations (RIs) may not adequately represent base background conditions. The second point was that it may be more prudent to establish SWMU-specific soil to groundwater target concentrations instead of using the NC DENR Method I Category S-3:G-1 Target Concentrations which are based on default values and not site-specific conditions.

The background concentrations used for several years at MCB, Camp Lejeune were compiled using data collected from soil borings located upgradient of several Remedial Investigation (RI) sites. It was later discovered that some of the RI sites were contaminated with inorganics. This discovery lead to the suspicion that background sample locations may also have been contaminated but to a lesser degree, therefore, possibly artificially inflating the average background concentration. It was decided that a new base background study should be conducted at MCB, Camp Lejeune. Soil samples will be collected from various locations throughout MCB, Camp Lejeune in areas not impacted by base activities to determine a base background concentration for inorganics. In addition, it was determined that a background study should be conducted in the vicinity of the SWMUs to establish SWMU-specific background conditions. NC DENR agreed that SWMUs could be gathered together into Areas of Concern (AOCs) based on geographical location, geology and type of SWMU, and background concentrations for inorganics could be established for each of these AOCs. NC DENR has suggested that the protocol outlined in Ohio Environmental Protection Agency's (OEPA's) Closure Plan Review Guidance for RCRA Facilities, Section 3.12 (Guidance for Statistical Evaluation of Hazardous Waste Constituent Levels in Soils, March 1999) would be a good guide for this study.

Formulas used in the USEPA's Soil Screening Guidance documents (EPA/540/R95/128 and EPA/540/R96/018) were used by NC DENR to calculate the soil to groundwater screening values (NC DENR Method I Category S-3:G-1 Target Concentrations). This approach is conservative with several assumed default values and assumptions that can be changed to site-specific data. One of the assumptions used in the calculation of the Method I Category S-3:G-1 Target Concentrations is that a half-acre area is contaminated at the screening level from the land surface to the top of the water table. Therefore, comparison of a single sample result to the soil to groundwater screening levels is not as appropriate as comparing the SWMU-wide average to them.

The formula used to calculate the Method I Category S-3:G-1 Target Concentrations assumed a default value for fraction of organic carbon (f_{oc}) of 0.001 which NC DENR suspects is quite low for MCB, Camp Lejeune. These are two of the assumptions used in the calculation of the default values used in the Method I Category S-3:G-1 Target Concentrations which create generic and conservative target concentrations. With a little bit of site specific data, numbers could be calculated using the formulas outlined in Method II Category S-3:G-1 that would result in more practical screening levels for the SWMUs.

Following completion of the Background Study, the results of the Phase I Confirmatory Study will be re-evaluated in relation to the inorganic analytical data and statistical evaluation of the background samples. Results of this study will provide a baseline by which all inorganics detected in soils collected from the SWMUs can be compared to assess whether inorganic constituents are the result of SWMU-specific activity or are naturally occurring. Additionally, some SWMUs will be sampled to determine the fraction of organic carbon (f_{oc}) in soils to allow the calculation of site specific soil to groundwater standards for semivolatiles. Based on this new evaluation/comparison, determinations will be made as to which SWMUs require additional investigation as part of the Phase II Confirmatory Study Investigation.

1.1 Objective of the Background Study SSP

The objective of the SSP is to present the sample collection and analysis strategy that will be used to obtain the background inorganic sampling data. The Background Study effort is based on the analytical data, data evaluation and recommendations of the Phase I SWMU Confirmatory Sampling Study as presented in the Phase I SWMU Confirmatory Sampling Report (Baker, 1999).

The Background Study investigation will provide the basis for inorganic statistical data to evaluate the Phase I Confirmatory Study data to determine further action that will need to be undertaken at the individual SWMUs. This study will consist of soil sampling to collect surface and subsurface soil samples for analysis of inorganics to provide the statistical base to assess whether inorganic concentrations are the result of SWMU-specific activity, are naturally occurring, or are of anthropogenic origin.

1.2 Report Organization

In addition to Section 1.0, the following sections are presented in this SSP:

- Section 2.0 - MCB, Camp Lejeune Background
- Section 3.0 - RCRA-Related History
- Section 4.0 – Background Study Field Investigation
- Section 5.0 - Management of Investigation Derived Waste
- Section 6.0 - Schedule
- Section 7.0 - References

Section 2.0 presents general background information such as location, topography, and geology. Section 3.0 summarizes the history of the Resource Conservation and Recovery Act (RCRA) activities associated with the MCB Camp Lejeune SWMUs. This section also presents a summary of the Phase I SWMU Confirmatory Sampling results. Section 4.0 presents the Background Study field investigation approach, a summary of the soil investigation to be conducted, the analytical program, the field investigation methods and procedures, and a discussion of the statistical methodology to be used. The management of investigation derived waste (IDW) is discussed in Section 5.0. The proposed investigation schedule is provided in Section 6.0. Section 7.0 presents the references used to prepare this Background Study SSP.

2.0 BACKGROUND

The following subsections present general information on location, topography and geology of MCB, Camp Lejeune. More specific information on the individual SWMUs can be found in Section 2.0 of the Phase I SWMU Confirmatory Sampling Report (Baker, 1999).

2.1 Location

MCB, Camp Lejeune is located within the Coastal Plain Physiographic Province. It is located in Onslow County, North Carolina, approximately 45 miles south of New Bern and 47 miles north of Wilmington. The facility covers approximately 236 square miles which includes the recent acquisition of approximately 64 square miles west of the facility within the Greater Sandy Run Area (GSRA) of the county. The military reservation is bisected by the New River, which flows in a southeasterly direction and forms a large estuary before entering the Atlantic Ocean.

The eastern border of MCB, Camp Lejeune is the Atlantic shoreline. The western and northwestern boundaries are U.S. Route 17 and State Route 24, respectively. The City of Jacksonville, North Carolina borders MCB, Camp Lejeune to the north.

Figure 2-1 is a location plan that depicts MBC, Camp Lejeune and is also an index for locations of Figures 2-2 through 2-6. The AOCs and their respective SWMUs are depicted on Figures 2-2 through 2-6.

2.2 Topography

The generally flat topography of MCB, Camp Lejeune is typical of the North Carolina Coastal Plain. Elevations on the base vary from sea level to 72 feet above mean sea level (msl); however, the elevation of most of Camp Lejeune is between 20 and 40 feet above msl.

Drainage at Camp Lejeune is generally toward the New River, except in areas near the coast, which drain through the Intracoastal Waterway. In developed areas, natural drainage has been altered by asphalt cover, storm sewers, and drainage ditches. Approximately 70 percent of Camp Lejeune is in broad, flat interstream areas. Drainage is poor in these areas and the soils are often wet (WAR, 1983). The U.S. Army Corps of Engineers has mapped the limits of the 100-year floodplain at Camp Lejeune at 7.0 feet above msl in the upper reaches of the New River increasing downstream to 11.0 feet above msl near the coastal area (WAR, 1983).

2.3 Geology

MCB, Camp Lejeune is within the Tidewater region of the Atlantic Coastal Plain Physiographic Province. The sediments of the Atlantic Coastal Plain consist mostly of interbedded sands, silts, clays, calcareous clays, shell beds, sandstone and limestone. These sediments are layered in interfingering beds and lenses that gently dip and thicken to the southeast to a combined thickness of approximately 1,500 feet. They were deposited in marine or near-shore environments and range in age from early Cretaceous to Quaternary time. Regionally, the sediments comprise 10 aquifers and nine confining units, which overlie igneous and metamorphic basement rocks of the pre-Cretaceous age. Seven of these aquifers and their associated confining units are present in the MCB, Camp Lejeune area (Cardinell, et al., 1993).

The lithology encountered during the Phase I Confirmatory Sampling Investigation consisted of primarily fine sand with varying amounts of silt and clay. In areas, silty and/or clayey strata predominated. Fill materials were also encountered at specific SWMUs. Refer to the boring logs in Appendix A of the Draft Phase I SWMU Confirmatory Sampling Report (Baker, 1999) for information regarding the lithology encountered at the individual SWMUs.

3.0 RCRA-RELATED HISTORY

This section provides a summary of the RCRA-related history of the SWMUs at MCB, Camp Lejeune, in addition to a summary of the Phase I SWMU Confirmatory Sampling Investigation.

3.1 RCRA History

An initial RCRA Facility Assessment (RFA) for MCB, Camp Lejeune, North Carolina was conducted by the U. S. Environmental Protection Agency (USEPA) Region IV and the North Carolina Department of Environment and Natural Resources (NC DENR) in January 1989. The RFA covered 76 SWMUs of which seven were determined to require confirmatory sampling, 23 to require an RCRA Facility Investigation (RFI), and 46 to require no further action (NFA). MCB, Camp Lejeune later expanded the initial RFA to include units such as landfills, surface impoundments, waste piles, tanks, container storage, septic tanks, drain fields, waste treatment units, and storm water conveyances. More than 3,500 SWMUs were identified during a preliminary review of MCB records. Visual site inspections were conducted on nearly 500 of these SWMUs. The findings from the RFA are presented in the document entitled RCRA Facility Assessment Report for Marine Corps Base, Camp Lejeune, North Carolina (EnSafe, 1996).

The 1996 RFA Report identified 41 Installation Restoration (IR) sites, 112 underground storage tank (UST) sites, and 56 SWMUs that required confirmatory sampling or corrective measures. Based on further negotiations between the state and MCB, Camp Lejeune, 62 SWMUs were identified as needing confirmatory sampling. These 62 SWMUs were investigated under the Phase I Confirmatory Study (Baker, 1999).

3.2 Summary of Phase I SWMU Confirmatory Study

The Phase I Confirmatory Study consisted of the investigation of soil, surface water and/or sediment at 62 SWMUs at MCB, Camp Lejeune. The individual SWMUs were evaluated based on the known or assumed contamination associated with the use or function of the SWMU. Specific analytical results for the individual SWMUs can be found in Section 4.0 of the Phase I SWMU Confirmatory Sampling Report (Baker, 1999).

The sample result for each SWMU were compared to appropriate screening criteria to determine if waste management activities at the SWMU had potentially impacted the environment. Typically, if contaminant concentrations exceeded the comparison criteria, further investigation activities were recommended for that individual SWMU. Table 3-1 provides a summary of Phase I Investigation results and recommendations.

Of the 62 SWMUs evaluated under the Phase I Investigation, Baker recommended that no further actions were necessary at 15 of the SWMUs, and that additional confirmatory investigations were required for 47 of the SWMUs. The SWMUs requiring no further action include: SWMUs 2, 5, 257, 260, 268, 275, 276, 277, 283, 284, 286, 292, 298, 310, and 337. The activities suggested for the SWMUs requiring additional investigations range from the collection of additional surface soil samples, to soil borings, to temporary groundwater monitoring wells to confirm the presence or absence of contamination. These additional investigative activities are scheduled to take place upon completion of this background study.

4.0 BACKGROUND STUDY FIELD INVESTIGATION

This section presents information pertinent to the Background Study field investigation including: the investigation objectives, the scope of soil investigations, the investigation methods, the analytical program, and the statistical methodology to be used to asses the data.

4.1 Background Study Sampling Objectives

There are three primary objectives of the Background Study Sampling effort:

- Establish inorganic background analytical data at AOCs to develop a statistical base as a screening criteria to evaluate the Phase I analytical results (i.e., confirm the presence or absence of contamination) at SWMUs;

- Develop specific data on pH for the evaluation of inorganics in soil and f_{oc} (fraction of organic carbon) to determine the partition coefficient (K_d) to develop screening criteria to evaluate organics in soil; and

- To provide a limited sampling of area unaffected by any waste management activities base-wide to develop a database that can be used to statistically compare inorganics at MCB, Camp Lejeune.

To meet these objectives, the Background Study field effort will consist of the following:

- Collection of surface and subsurface soil samples within the identified AOCs with analysis for inorganics and pH;

- Collection of f_{oc} data from individual SWMUs that have exhibited organic contamination; and

- Collection of surface and subsurface soil samples at identified areas within the base that have been unaffected by base activities.

Based on the results of the Background Study Investigation, the results of the Phase I Confirmatory Study will be re-evaluated to determine recommendations for further action. Recommendations may range from proposing a RFI to more fully investigate and characterize a SWMU, proposing the collection of additional confirmatory samples (Phase II), or to proposing no further actions for the SWMU.

The base-wide background investigation will provide information/data on naturally occurring concentrations of inorganics in surface and subsurface soils at MCB, Camp Lejeune. The location of the samples are discussed in Section 4.2. This data will be used to evaluate inorganic concentrations obtained from the AOC specific Background Study to assess whether the inorganic concentrations are naturally occurring or related to activities (past and/or present) within the AOCs. Future investigations at the SWMUs or newly identified areas/sites at MCB, Camp Lejeune will utilize this background information for evaluation purposes.

4.2 Field Investigation Approach

SWMU Specific Study

Based on the results and evaluation of data from the Phase I Confirmatory Sampling Investigation, a statistically based background screening criteria for inorganics was determined to be appropriate. Table 4-1 presents a summary of the Phase I Confirmatory Study SWMUs with the AOC that it has been grouped in for the Background Study. Table 4-2 presents the number of sampling locations proposed for each of the identified AOCs.

Soil samples (surface and subsurface) will be collected at each of the sampling locations proposed for the eleven AOCs. Samples will be collected using the direct push method. Surface soil samples will be collected from the 0 to 1 foot below ground surface (bgs) interval. The subsurface soil samples will be collected just above the water table. As indicated on Table 4-2 and on Figures 2-2 through 2-6, there are 165 AOC soil sample locations. Based on these sample locations, there will be 165 surface soil samples and 165 subsurface soil samples collected for laboratory analysis.

Enough sample will be collected to provide for inorganic and pH analyses for both the surface and subsurface soil samples collected at each location. Additional samples will be collected at specific SWMUs for f_{oc} analysis where site-specific soil to groundwater screening levels for organics need to be established. Table 4-3 presents the SWMUs with associated Phase I locations to be sampled for f_{oc} analysis.

Base-Wide Study

There are 50 proposed base background boring locations. The proposed number of locations was based on the potential for varying lithologies across the base and the locations of existing or potential investigative sites. Surface and subsurface soils will be collected from each location. The fifty locations proposed as part of this investigation will collect 10-15 samples of different lithologies (i.e., silty clay, clayey silt, clayey sand, silty sand, etc.). Therefore, the database will be segregated by depth (surficial vs. subsurface), lithologies, and location. Figure 4-1 presents the proposed base-wide sampling locations. These locations will have to be reviewed by MCB personnel as to their appropriateness. Base-wide background locations will be sampled using the same protocols and methodologies as for the AOCs. Surface and subsurface soil samples will be collected from each location for inorganic analyses. It is also proposed that approximately 25 sample locations have surface and subsurface soil samples submitted for pH analysis. This will provide base-wide information on pH values that can be used in association with the inorganic concentrations for current and future site evaluations.

4.3 Analytical Program

The soil samples collected for analysis of inorganics during the Background Study Investigation (i.e., both SWMU specific and Base-wide) will be submitted to an off-site laboratory for analysis. The laboratory analyses proposed for the Background Study is RCRA metals (Method 6010/7471). Analysis for pH will also be submitted to the off-site laboratory. This will be in accordance with ASTM Standard D 4972-95A, US EPA Method 9045. Total organic carbon analysis, for determination of f_{oc}, will be conducted in accordance with ASTM Standard D 3178.

4.4 Field Investigation Methods and Procedures

Soil sample collection will be performed in accordance with the techniques and procedures presented in the Final Solid Waste Management Unit (SWMU) Confirmatory Sampling Project Plans (Baker, 1997). These Project Plans include the Field Sampling and Analysis Plan (FSAP), Quality Assurance Project Plan (QAPP) and the Health and Safety Plan (HASP).

4.5 Statistical Methodology

The statistical methodology to be used for the Background Study at MCB Camp Lejeune is the Ohio EPA Closure Plan Review Guidance for RCRA Facilities (Section 3.12 – Guidance for Statistical Evaluation of Hazardous Waste Constituent Levels in Soil) (March 1999). A copy of Section 3.12 is included as Appendix A.

5.0 MANAGEMENT OF INVESTIGATION DERIVED WASTE

Primarily liquid investigation derived waste (IDW) will be generated and managed during the Background Study investigation. Due to the use of the direct push sampling method, it is anticipated that there will be little to no solid waste generated during the investigation. If solid wastes are generated, they will be contained in 55-gallon drums. As no groundwater investigation will be included in the background study, the only liquid wastes will be from the decontamination of sampling equipment. This waste will be stored in 55-gallon drums.

If needed, a composite sample will be collected from the solid wastes generated and submitted for analysis of Target Compound Leaching Procedure (TCLP) organics and inorganics, and RCRA Hazardous Waste Characteristics in order to access disposal options. A single sample will be collected from the drums used to store the decontamination liquid IDW during the investigation. This sample will be analyzed for Contract Laboratory Protocol (CLP) organics and inorganics. Based on the analytical results and the approval of the Atlantic Division, Naval Facilities Engineering Command (LANTDIV) and MCB, Camp Lejeune, liquid IDW will be transported to an on-Base facility for treatment and disposal. If possible, based on the solid IDW analytical results, solid wastes will be disposed of at the Base, otherwise it will be contracted for removal, transport and disposal at a certified facility.

6.0 PROPOSED SCHEDULE

A proposed schedule for the deliverables and milestones associated with the Background Study Investigation is presented on Figure 6-1 and detailed below. The assumed start date is June 1, 2000. The day in the "()" represents the proposed deliverable or end date for each task/activity.

- Receive state's concurrence on the proposed Background Study SSP (Day 1)
- Submit the Final Background Study SSP (Day 14)
- Procurement of Subcontractors (Day 14)
- Mobilize to the field (Day 21)
- Conduct the Field Investigation (61)
- Demobilize from the field (Day 62)
- Receive analytical results (Day 90)
- Receive validated analytical results (104)
- Statistical evaluation of data (Day 118)
- Submit the Draft Background Study Report/Results (Day 158)
- Receive state comments on the Draft Background Study Report/Results (Day 188)
- Respond to the state comments on the Draft Background Study Report and submit Final Report (Day 218)

7.0 REFERENCES

Baker Environmental, Inc. (Baker). 1999. Phase I SWMU Confirmatory Sampling Report, Marine Corps Base Camp Lejeune, North Carolina. Final. Prepared for the Naval Facilities Engineering Command, Atlantic Division, Norfolk, Virginia. October 1998. (A Revised Final version of this report is being prepared).

Baker Environmental, Inc. (Baker). 1997. Solid Waste Management Unit (SWMU) Confirmatory Sampling Project Plans, Marine Corps Base, Camp Lejeune, North Carolina. Final. Prepared for the Naval facilities Engineering Command, Atlantic Division, Norfolk, Virginia. April 1997.

Cardinell, Alex P. et al. 1993. Hydrogeologic Framework of U.S. Marine Corps Base at Camp Lejeune, North Carolina. U.S. Geological Survey, Water-Resources Investigations Report 93-4049.

Environmental and Safety Designs, Inc. (EnSafe). 1996. RCRA Facility Assessment Report for Marine Corps Base Camp Lejeune, North Carolina. Final. Prepared for the Naval Facilities Engineering Command, Atlantic Division, Norfolk, Virginia. July 25, 1996.

North Carolina Department of Environment and Natural Resources (NC DENR). 1996. North Carolina Risk Analysis Framework. Methods for Determining Contaminant Target Concentrations in Soil & Groundwater. Draft. November 1996.

Ohio EPA. 1999. Closure Plan Review Guidance for RCRA Facilities. March 1999.

USEPA/NRMRL, 1997. Characterization of Organic Matter in Soils and Aquifer Solids. April 1997.

Water and Air Research, Inc. (WAR). 1983. Initial Assessment Study of Marine Corps Base Camp Lejeune, North Carolina. Prepared for Naval Energy and Environmental Support Activity.

TABLES

TABLE 3-1
PHASE I SWMU INVESTIGATION SUMMARY
BACKGROUND STUDY - CTO-371
MCB, CAMP LEJEUNE, NORTH CAROLINA

SWMU Identification	SWMU Description	Summary of Results	Recommendations
SWMU 2 1700 Pond A	Concrete neutralization/settling pond associated with the Steam Plant. Receives runoff from coal pile	Mercury was detected at concentrations exceeding primary criteria, but below the secondary criteria.	Further Action – Phase II Confirmatory Samples
SWMU 5 575 Rack	Wash water collection structure and oil/water separator associated with the vehicle wash racks	Mercury was detected at concentrations exceeding primary criteria, but below the secondary criteria.	No Further Action
SWMU 43 Pest Control Shop (IR Site No. 11)	Oil/water separator associated with wash area for pesticide-carrying vehicles	SVOCs, two pesticides--4,4'-DDT and chlordane, and three metals—arsenic, chromium, and mercury detected at concentrations exceeding criteria. Mercury concentrations did not exceed the secondary criteria.	Further Action - Phase II Confirmatory Samples
SWMU 46 Montford Point Dump Site (IR Site No. 15)	Potential sewage treatment plant sludge disposal area	Four metals—arsenic, cadmium, lead, and mercury detected at concentrations exceeding criteria. Mercury concentrations did not exceed secondary criteria.	Further Action - Phase II Confirmatory Samples
SWMU 53 Coal Storage Area (IR Site No. 26)	Concrete coal storage area associated with the Steam Plant	For, SWMUs 53 and 296, one SVOC and two metals mercury and arsenic were detected at concentrations exceeding criteria. Mercury concentrations did not exceed secondary criteria.	Further Action - Phase II Confirmatory Samples
SWMU 89 SLCH785 Basin	Oil/water separator associated with a vehicle wash rack	VOCs, SVOCs, and arsenic detected at concentrations exceeding criteria.	Further Action - Phase II Confirmatory Samples
SWMU 253 1205 Above Ground Storage Tank	Former location of a 500- gallon used oil AST	Arsenic was detected at concentration exceeding criteria.	Further Action - Phase II Confirmatory Samples

TABLE 3-1 (Continued)
PHASE I SWMU INVESTIGATION SUMMARY
BACKGROUND STUDY - CTO-371
MCB, CAMP LEJEUNE, NORTH CAROLINA

SWMU Identification	SWMU Description	Summary of Results	Recommendations
SWMU 254 1408 Dumpster	Solid waste dumpster that at one point reportedly contained paint cans and a 1-gallon container of Citrakleen	SVOCs, arsenic and mercury detected at concentrations exceeding criteria. Arsenic and mercury concentrations did not exceed secondary criteria.	Further Action - Phase II Confirmatory Samples
SWMU 255 1502 Oil/Water Separator No. 1	Oil/water separator and grit chamber associated with vehicle maintenance facility	Two SVOCs and two metals - arsenic and mercury detected at concentrations exceeding criteria. Arsenic and mercury did not exceed secondary criteria.	Further Action - Phase II Confirmatory Samples
SWMU 256 1700 Oil/Water Separator No. 1	Oil/water separator associated with an AST at the Steam Plant	Two SVOCs detected at concentrations exceeding criteria.	Further Action - Phase II Confirmatory Samples
SWMU 257 1700 Oil/Water Separator No. 2	Oil/water separator associated with an AST at the Steam Plant	No compound concentrations exceeded criteria.	No Further Action
SWMU 258 S1745 Oil/Water Separator	Oil/water separator and grit chamber associated with a vehicle wash rack	Three VOCs, cadmium, and mercury detected at concentrations exceeding criteria. The mercury concentrations were below the secondary criteria.	No Further Action
SWMU 260 1780 Oil/Water Separator No. 1	Oil/water separator associated with a vehicle wash rack	No compound concentrations exceeded criteria.	No Further Action
SWMU 261 1780 Underground Storage Tank No. 1	550-gallon UST. Stores oil, grease and water associated with an oil/water separator (SWMU 297)	For SWMUs 261 and 297, two VOCs, arsenic, cadmium, chromium, lead, and mercury detected at concentrations exceeding criteria. Mercury concentrations were below the secondary criteria.	Further Action - Phase II Confirmatory Samples

TABLE 3-1 (Continued)
PHASE I SWMU INVESTIGATION SUMMARY
BACKGROUND STUDY - CTO-371
MCB, CAMP LEJEUNE, NORTH CAROLINA

SWMU Identification	SWMU Description	Summary of Results	Recommendations
SWMU 262 1780 Underground Storage Tank No. 2	550-gallon UST. Stores oil, grease and water associated with an oil/water separator (SWMU 298)	Arsenic detected at concentrations exceeding criteria in one subsurface soil sample.	Further Action - Phase II Confirmatory Samples
SWMU 264 2611 Container	Once tar-stained area that was subsequently covered with wood chips. Wood chips and tar no longer present	One SVOC—pentachloro-phenol, one pesticide--chlordane, and one metal—arsenic detected at concentrations exceeding criteria.	Further Action - Phase II Confirmatory Samples
SWMU 265 2615 Oil/Water Separator	Oil/water separator associated with No. 6 fuel oil loading area	The SVOC benzo(a)pyrene detected at concentration exceeding criteria in one surface soil sample.	Further Action - Phase II Confirmatory Samples
SWMU 268 522 Dumpster	Solid waste dumpster	No compound concentrations exceeded criteria.	No Further Action
SWMU 269 816 Oil/Water Separator	Former location of a oil/water separator and vehicle wash rack	Arsenic detected at concentration exceeding criteria.	Further Action - Phase II Confirmatory Samples
SWMU 272 AS137 Oil/Water Separator	Recently replaced oil/water separator	Two VOCs – methylene chloride and 1,4 dichlorobenzene, four SVOCs--2-chlorophenol, naphthalene, benzo(a)pyrene, and pentachlorophenol, and two metals--arsenic and mercury detected at concentrations exceeding criteria.	Further Action - Phase II Confirmatory Samples
SWMU 273 BA128/BA105 Dumpster	Former solid waste dumpster location. Reportedly had a one-time release of petroleum or oil.	Arsenic detected at concentrations exceeding criteria.	Further Action - Phase II Confirmatory Samples
SWMU 275 BB48 Dumpster	Solid waste dumpster which at one time reportedly showed evidence of a spill	No compound concentrations exceeded criteria.	No Further Action
SWMU 276 BB49 Dumpster	Solid waste dumpster while at one time reportedly showed evidence of a POL spill	No compound concentrations exceeded criteria.	No Further Action

TABLE 3-1 (Continued)
PHASE I SWMU INVESTIGATION SUMMARY
BACKGROUND STUDY - CTO-371
MCB, CAMP LEJEUNE, NORTH CAROLINA

SWMU Identification	SWMU Description	Summary of Results	Recommendations
SWMU 277 FC120 Oil/Water Separator	Oil/water separator associated with a wash rack and adjacent to IR Site No. 1	No compound concentrations exceeded criteria.	No Further Action
SWMU 279 FC200 Oil/Water Separator	Oil/water separator associated with a vehicle wash rack	The SVOC benzo(a)pyrene and arsenic were detected at concentrations exceeding criteria. Arsenic concentrations were below the secondary criteria.	No Further Action
SWMU 280 FC285 Above Ground Storage Tank	Former location of a used oil AST	Arsenic detected at concentrations exceeding criteria.	No Further Action
SWMU 283 FC279 Release	Small area adjacent to a materials storage area with evidence of distressed vegetation	No compound concentrations exceeded criteria.	No Further Action
SWMU 284 S947 Container	Former location of roll-off box which contained POL-contaminated soil. Associated with SWMU 286.	For SWMUs 284 and 286, arsenic and mercury concentrations exceeded the primary criteria but not the secondary criteria.	No Further Action
SWMU 285 S947 Oil/Water Separator	Oil/water separator associated with a storm water containment system	One VOC , five SVOCs, and arsenic detected at concentrations exceeding criteria.	Further Action - Phase II Confirmatory Samples
SWMU 286 S947 Pile	Former POL-contaminated storage area for soil. Currently regraded and paved. Associated with SWMU 284.	For SWMUs 284 and 286, arsenic and mercury concentrations exceeded the primary criteria but not the secondary criteria.	No Further Action

TABLE 3-1 (Continued)
PHASE I SWMU INVESTIGATION SUMMARY
BACKGROUND STUDY - CTO-371
MCB, CAMP LEJEUNE, NORTH CAROLINA

SWMU Identification	SWMU Description	Summary of Results	Recommendations
SWMU 291 034 Ditch	Storm water drainage ditch and scour area that historically received runoff from an oil/water separator and wash rack	For soil, arsenic and chromium detected above screening criteria. For surface water, one VOC – tetrachloroethene detected above screening criteria. For sediment, one SVOC – acenaphthene, one pesticide -- 4-4'-DDE, cadmium and mercury detected at concentrations exceeding criteria.	Further Action - Phase II Confirmatory Samples
SWMU 292 1106/1107 Above Ground Storage Tank	500-gallon AST that stores waste oil and antifreeze	Mercury concentrations exceeded the primary criteria but not the secondary criteria.	No Further Action
SWMU 293 1106/1107 Oil/Water Separator	Oil/water separator contains oil filters, waste oil, antifreeze, and possibly solvents	Lead and mercury detected at concentrations exceeding criteria. Mercury concentrations were below the secondary criteria.	Further Action - Phase II Confirmatory Samples
SWMU 294 1203 Oil/Water Separator	Oil/water separator and grit chamber associated with a vehicle wash rack	Mercury detected at concentrations exceeding criteria.	Further Action - Phase II Confirmatory Samples
SWMU 295 1601 Above Ground Storage Tank	AST in an area of known TCE groundwater contamination	The SVOC naphthalene and the metal arsenic detected at concentrations exceeding criteria. Arsenic concentrations were below the secondary criteria.	Further Action - Phase II Confirmatory Samples
SWMU 296 1700 Basin B	Collection basin that receives runoff from the coal pile	For, SWMUs 53 and 296, one SVOC and two metals mercury and arsenic were detected at concentrations exceeding criteria. Mercury concentrations did not exceed secondary criteria.	No Further Action

TABLE 3-1 (Continued)
PHASE I SWMU INVESTIGATION SUMMARY
BACKGROUND STUDY - CTO-371
MCB, CAMP LEJEUNE, NORTH CAROLINA

SWMU Identification	SWMU Description	Summary of Results	Recommendations
SWMU 297 1780 Oil/Water Separator No. 2	Oil/water separator associated with SWMU 261. Contains oil, grease and water	For SWMUs 261 and 297, two VOCs, arsenic, cadmium, chromium, lead, and mercury detected at concentrations exceeding criteria. Mercury concentrations were below the secondary criteria.	Further Action - Phase II Confirmatory Samples
SWMU 298 1780 Oil/Water Separator No. 3	Oil/water separator associated with SWMU 262. Contains oil, grease, and water.	No compound concentrations exceeded criteria.	No Further Action
SWMU 299 AS114 Above Ground Storage Tank	Used oil AST. Significant staining noted on tank exterior	One VOC, several SVOCs, and six metals-- arsenic, cadmium, chromium, lead, mercury, and silver detected at concentrations exceeding criteria.	Further Action - Phase II Confirmatory Samples
SWMU 300 AS118 Above Ground Storage Tank	Used motor oil AST	Two SVOCs, arsenic and mercury detected at concentrations exceeding criteria. The arsenic and mercury concentrations were below the secondary criteria.	Further Action - Phase II Confirmatory Samples
SWMU 301 AS4115 Above Ground Storage Tank	Two ASTs that contain POLs	Arsenic and mercury detected at concentrations exceeding criteria. Mercury concentrations were below secondary criteria.	Further Action - Phase II Confirmatory Samples
SWMU 302 AS563 Above Ground Storage Tank	AST that contains used engine, hydraulic and transmission oil	The SVOC benzo(a)pyrene and the metal cadmium detected at concentrations exceeding criteria.	Further Action - Phase II Confirmatory Samples
SWMU 303 AS515 Above Ground Storage Tank	Two ASTs that are labeled as "Hydraulic Fluid, Engine and Transmission Oils Only, No Solvents or Other Chemicals"	One VOC, three SVOCs, arsenic and chromium detected at concentrations exceeding criteria.	Further Action - Phase II Confirmatory Samples
SWMU 304 BA103 Oil/Water Separator	Oil/water separator connected to a drain field	Arsenic detected at concentration exceeding criteria.	Further Action - Phase II Confirmatory Samples

TABLE 3-1 (Continued)
PHASE I SWMU INVESTIGATION SUMMARY
BACKGROUND STUDY - CTO-371
MCB, CAMP LEJEUNE, NORTH CAROLINA

SWMU Identification	SWMU Description	Summary of Results	Recommendations
SWMU 305 BB224 Pile	Former location of soil pile which reportedly contained grease and contaminated soil	Arsenic detected at concentration exceeding criteria.	Further Action - Phase II Confirmatory Samples
SWMU 306 FC230 Oil/Water Separator	Oil/water separator associated with vehicle wash area	Silver and mercury detected at concentrations exceeding criteria. Mercury concentrations were below the secondary criteria.	Further Action - Phase II Confirmatory Samples
SWMU 307 G649 Wash Rack	Oil/water separator and vehicle wash rack	Arsenic and mercury detected at concentrations exceeding criteria.	Further Action - Phase II Confirmatory Samples
SWMU 308 GP109 Oil/Water Separator	Oil/water separator associated with a vehicle wash rack	The SVOC bis (2-chloroethyl) ether detected at concentrations exceeding criteria.	Further Action - Phase II Confirmatory Samples
SWMU 309 NH118 Underground Storage Tank	Waste oil UST and AST	Arsenic detected at concentrations exceeding criteria.	Further Action - Phase II Confirmatory Samples
SWMU 310 PT33 Pond Oil/Water Separator	Several earthen impoundments used for dewatering of cooking grease	Arsenic detected at concentrations exceeding the primary criteria but below the secondary criteria.	No Further Action
SWMU 311 S1619 Oil/Water Separator	Oil/water separator associated with a vehicle wash rack	Two VOCs and five metals -- arsenic, cadmium, chromium, lead, and mercury detected at concentrations exceeding criteria. Mercury concentrations were below the secondary criteria.	Further Action - Phase II Confirmatory Samples
SWMU 312 Oil Water Separator S-1735 (S-1698)	Oil/water separator that receives steam condensate from the Steam Plant (Building 1700)	The SVOC benzo(a)pyrene and the metals arsenic and mercury detected at concentrations exceeding criteria. Mercury concentrations were below the secondary criteria.	Further Action - Phase II Confirmatory Samples

TABLE 3-1 (Continued)
PHASE I SWMU INVESTIGATION SUMMARY
BACKGROUND STUDY - CTO-371
MCB, CAMP LEJEUNE, NORTH CAROLINA

SWMU Identification	SWMU Description	Summary of Results	Recommendations
SWMU 313 S1753 Oil/Water Separator	Oil/water separator associated with a vehicle and equipment wash area	Arsenic, mercury and silver detected at concentrations exceeding criteria. Mercury concentrations were below the secondary criteria.	Further Action - Phase II Confirmatory Samples
SWMU 314 SM187 Oil/Water Separator	Oil/water separator associated with a vehicle wash rack	The SVOC benzo(a)pyrene and the metals arsenic and mercury detected at concentrations exceeding criteria. Mercury concentrations were below the secondary criteria.	Further Action - Phase II Confirmatory Samples
SWMU 315 SM269 Oil/Water Separator Near Building M200	Oil/water separator associated with a vehicle wash rack. Unit may have been used for disposal of waste oil	The SVOC pentachlorophenol and three metals -- arsenic, mercury, and silver detected at concentrations exceeding criteria. Mercury concentrations were below the secondary criteria.	Further Action - Phase II Confirmatory Samples
SWMU 316 TC773 Oil/Water Separator	Oil/water separator and vehicle wash rack	The SVOC benzo(a)pyrene and the metal arsenic detected at concentrations exceeding criteria. Arsenic concentrations were below the secondary criteria.	No Further Action
SWMU 317 TT2453 Release	Area near a used antifreeze AST where a release had reportedly occurred	Arsenic, lead and mercury detected at concentrations exceeding criteria. Mercury concentrations were below the secondary criteria.	Further Action - Phase II Confirmatory Samples
SWMU 318 AS515 Oil/Water Separator	Oil/water separator and grit chamber associated with a helicopter wash pad	Two VOCs, several SVOCs, and five metals -- arsenic, cadmium, chromium, mercury, and silver detected at concentrations exceeding criteria.	Further Action - Phase II Confirmatory Samples

TABLE 3-1 (Continued)
PHASE I SWMU INVESTIGATION SUMMARY
BACKGROUND STUDY - CTO-371
MCB, CAMP LEJEUNE, NORTH CAROLINA

SWMU Identification	SWMU Description	Summary of Results	Recommendations
SWMU 319 Camp Geiger Wastewater Treatment Plant	An AST at the Camp Geiger Wastewater Treatment Plant	Three SVOCs, arsenic and mercury detected at concentrations exceeding criteria. Arsenic concentrations were below the secondary criteria.	Further Action - Phase II Confirmatory Samples
SWMU 336 AS4106 Paint Stripper	Two paint stripping vats.	The floor drains located on either side of the vats contained no sediments. No samples were collected from this SWMU.	Further Action - Phase II Confirmatory Samples
SWMU 337 AS518 Paint Stripper	Two paint stripping vats in an organic stripping room.	Arsenic detected at concentrations exceeding the primary criteria but below the secondary criteria.	No Further Action
SWMU 339 AS4146 Sand Blasting Area	Covered sand blasting area	For soil, one VOC , one SVOC, and arsenic detected at concentrations exceeding criteria. For sediment, four SVOCs and four metals -- cadmium, chromium, lead and silver detected at concentrations exceeding criteria.	Further Action - Phase II Confirmatory Samples

Notes:

AST = aboveground storage tank
IR = Installation Restoration
POL = Petroleum, Oil and Lubricants
SVOC = semivolatile organic compounds
SWMU = Solid Waste Management Unit
UST = underground storage tank
VOC = volatile organic compound

TABLE 3-2
PHASE I SWMU INVESTIGATION SUMMARY
BACKGROUND STUDY - CTO-371
MCB, CAMP LEJEUNE, NORTH CAROLINA

SWMU Identification	SWMU Description	Summary of Results	Recommendations
SWMU 2 1700 Pond A	Concrete neutralization/settling pond associated with the Steam Plant. Receives runoff from coal pile	Mercury was detected at concentrations exceeding primary criteria, but below the secondary criteria.	No Further Action
SWMU 5 575 Rack	Wash water collection structure and oil/water separator associated with the vehicle wash racks	Mercury was detected at concentrations exceeding primary criteria, but below the secondary criteria.	No Further Action
SWMU 43 Pest Control Shop (IR Site No. 11)	Oil/water separator associated with wash area for pesticide-carrying vehicles	SVOCs, two pesticides--4,4'-DDT and chlordane, and three metals--arsenic, chromium, and mercury detected at concentrations exceeding criteria. Mercury concentrations did not exceed the secondary criteria.	Further Action - Phase II Confirmatory Samples
SWMU 46 Montford Point Dump Site (IR Site No. 15)	Potential sewage treatment plant sludge disposal area	Four metals--arsenic, cadmium, lead, and mercury detected at concentrations exceeding criteria. Mercury concentrations did not exceed secondary criteria.	Further Action - Phase II Confirmatory Samples
SWMU 53 Coal Storage Area (IR Site No. 26)	Concrete coal storage area associated with the Steam Plant	For, SWMUs 53 and 296, one SVOC and two metals mercury and arsenic were detected at concentrations exceeding criteria. Mercury concentrations did not exceed secondary criteria.	Further Action - Phase II Confirmatory Samples
SWMU 89 SLCH785 Basin	Oil/water separator associated with a vehicle wash rack	VOCs, SVOCs, and arsenic detected at concentrations exceeding criteria.	Further Action - Phase II Confirmatory Samples
SWMU 253 1205 Above Ground Storage Tank	Former location of a 500- gallon used oil AST	Arsenic was detected at concentration exceeding criteria.	Further Action - Phase II Confirmatory Samples

TABLE 3-2 (Continued)
PHASE I SWMU INVESTIGATION SUMMARY
BACKGROUND STUDY - CTO-371
MCB, CAMP LEJEUNE, NORTH CAROLINA

SWMU Identification	SWMU Description	Summary of Results	Recommendations
SWMU 254 1408 Dumpster	Solid waste dumpster that at one point reportedly contained paint cans and a 1-gallon container of Citrakleen	SVOCs, arsenic and mercury detected at concentrations exceeding criteria. Arsenic and mercury concentrations did not exceed secondary criteria.	Further Action - Phase II Confirmatory Samples
SWMU 255 1502 Oil/Water Separator No. 1	Oil/water separator and grit chamber associated with vehicle maintenance facility	Two SVOCs and two metals - arsenic and mercury detected at concentrations exceeding criteria. Arsenic and mercury did not exceed secondary criteria.	Further Action - Phase II Confirmatory Samples
SWMU 256 1700 Oil/Water Separator No. 1	Oil/water separator associated with an AST at the Steam Plant	Two SVOCs detected at concentrations exceeding criteria.	Further Action - Phase II Confirmatory Samples
SWMU 257 1700 Oil/Water Separator No. 2	Oil/water separator associated with an AST at the Steam Plant	No compound concentrations exceeded criteria.	No Further Action
SWMU 258 S1745 Oil/Water Separator	Oil/water separator and grit chamber associated with a vehicle wash rack	Three VOCs, cadmium, and mercury detected at concentrations exceeding criteria. The mercury concentrations were below the secondary criteria.	Further Action - Phase II Confirmatory Samples
SWMU 260 1780 Oil/Water Separator No. 1	Oil/water separator associated with a vehicle wash rack	No compound concentrations exceeded criteria.	No Further Action
SWMU 261 1780 Underground Storage Tank No. 1	550-gallon UST. Stores oil, grease and water associated with an oil/water separator (SWMU 297)	For SWMUs 261 and 297, two VOCs, arsenic, cadmium, chromium, lead, and mercury detected at concentrations exceeding criteria. Mercury concentrations were below the secondary criteria.	Further Action - Phase II Confirmatory Samples

TABLE 3-2 (Continued)
PHASE I SWMU INVESTIGATION SUMMARY
BACKGROUND STUDY - CTO-371
MCB, CAMP LEJEUNE, NORTH CAROLINA

SWMU Identification	SWMU Description	Summary of Results	Recommendations
SWMU 262 1780 Underground Storage Tank No. 2	550-gallon UST. Stores oil, grease and water associated with an oil/water separator (SWMU 298)	Arsenic detected at concentrations exceeding criteria in one subsurface soil sample.	Further Action - Phase II Confirmatory Samples
SWMU 264 2611 Container	Once tar-stained area that was subsequently covered with wood chips. Wood chips and tar no longer present	One SVOC--pentachloro-phenol, one pesticide--chlordane, and one metal--arsenic detected at concentrations exceeding criteria.	Further Action - Phase II Confirmatory Samples
SWMU 265 2615 Oil/Water Separator	Oil/water separator associated with No. 6 fuel oil loading area	The SVOC benzo(a)pyrene detected at concentration exceeding criteria in one surface soil sample.	Further Action - Phase II Confirmatory Samples
SWMU 268 522 Dumpster	Solid waste dumpster	No compound concentrations exceeded criteria.	No Further Action
SWMU 269 816 Oil/Water Separator	Former location of a oil/water separator and vehicle wash rack	Arsenic detected at concentration exceeding criteria.	Further Action - Phase II Confirmatory Samples
SWMU 272 AS137 Oil/Water Separator	Recently replaced oil/water separator	Two VOCs -- methylene chloride and 1,4 dichlorobenzene, four SVOCs--2-chlorophenol, naphthalene, benzo(a)pyrene, and pentachlorophenol, and two metals--arsenic and mercury detected at concentrations exceeding criteria.	Further Action - Phase II Confirmatory Samples
SWMU 273 BA128/BA105 Dumpster	Former solid waste dumpster location. Reportedly had a one-time release of petroleum or oil.	Arsenic detected at concentrations exceeding criteria.	Further Action - Phase II Confirmatory Samples
SWMU 275 BB48 Dumpster	Solid waste dumpster which at one time reportedly showed evidence of a spill	No compound concentrations exceeded criteria.	No Further Action
SWMU 276 BB49 Dumpster	Solid waste dumpster while at one time reportedly showed evidence of a POL spill	No compound concentrations exceeded criteria.	No Further Action

TABLE 3-2 (Continued)
PHASE I SWMU INVESTIGATION SUMMARY
BACKGROUND STUDY - CTO-371
MCB, CAMP LEJEUNE, NORTH CAROLINA

SWMU Identification	SWMU Description	Summary of Results	Recommendations
SWMU 277 FC120 Oil/Water Separator	Oil/water separator associated with a wash rack and adjacent to IR Site No. 1	No compound concentrations exceeded criteria.	No Further Action
SWMU 279 FC200 Oil/Water Separator	Oil/water separator associated with a vehicle wash rack	The SVOC benzo(a)pyrene and arsenic were detected at concentrations exceeding criteria. Arsenic concentrations were below the secondary criteria.	Further Action - Phase II Confirmatory Samples
SWMU 280 FC285 Above Ground Storage Tank	Former location of a used oil AST	Arsenic detected at concentrations exceeding criteria.	Further Action - Phase II Confirmatory Samples
SWMU 283 FC279 Release	Small area adjacent to a materials storage area with evidence of distressed vegetation	No compound concentrations exceeded criteria.	No Further Action
SWMU 284 S947 Container	Former location of roll-off box which contained POL-contaminated soil. Associated with SWMU 286.	For SWMUs 284 and 286, arsenic and mercury concentrations exceeded the primary criteria but not the secondary criteria.	No Further Action
SWMU 285 S947 Oil/Water Separator	Oil/water separator associated with a storm water containment system	One VOC , five SVOCs, and arsenic detected at concentrations exceeding criteria.	Further Action - Phase II Confirmatory Samples
SWMU 286 S947 Pile	Former POL-contaminated storage area for soil. Currently regraded and paved. Associated with SWMU 284.	For SWMUs 284 and 286, arsenic and mercury concentrations exceeded the primary criteria but not the secondary criteria.	No Further Action

TABLE 3-2 (Continued)
PHASE I SWMU INVESTIGATION SUMMARY
BACKGROUND STUDY - CTO-371
MCB, CAMP LEJEUNE, NORTH CAROLINA

SWMU Identification	SWMU Description	Summary of Results	Recommendations
SWMU 291 034 Ditch	Storm water drainage ditch and scour area that historically received runoff from an oil/water separator and wash rack	For soil, arsenic and chromium detected above screening criteria. For surface water, one VOC -- tetrachloroethene detected above screening criteria. For sediment, one SVOC -- acenaphthene, one pesticide -- 4-4'-DDE, cadmium and mercury detected at concentrations exceeding criteria.	Further Action - Phase II Confirmatory Samples
SWMU 292 1106/1107 Above Ground Storage Tank	500-gallon AST that stores waste oil and antifreeze	Mercury concentrations exceeded the primary criteria but not the secondary criteria.	No Further Action
SWMU 293 1106/1107 Oil/Water Separator	Oil/water separator contains oil filters, waste oil, antifreeze, and possibly solvents	Lead and mercury detected at concentrations exceeding criteria. Mercury concentrations were below the secondary criteria.	Further Action - Phase II Confirmatory Samples
SWMU 294 1203 Oil/Water Separator	Oil/water separator and grit chamber associated with a vehicle wash rack	Mercury detected at concentrations exceeding criteria.	Further Action - Phase II Confirmatory Samples
SWMU 295 1601 Above Ground Storage Tank	AST in an area of known TCE groundwater contamination	The SVOC naphthalene and the metal arsenic detected at concentrations exceeding criteria. Arsenic concentrations were below the secondary criteria.	Further Action - Phase II Confirmatory Samples
SWMU 296 1700 Basin B	Collection basin that receives runoff from the coal pile	For, SWMUs 53 and 296, one SVOC and two metals mercury and arsenic were detected at concentrations exceeding criteria. Mercury concentrations did not exceed secondary criteria.	Further Action - Phase II Confirmatory Samples

TABLE 3-2 (Continued)
PHASE I SWMU INVESTIGATION SUMMARY
BACKGROUND STUDY - CTO-371
MCB, CAMP LEJEUNE, NORTH CAROLINA

SWMU Identification	SWMU Description	Summary of Results	Recommendations
SWMU 297 1780 Oil/Water Separator No. 2	Oil/water separator associated with SWMU 261. Contains oil, grease and water	For SWMUs 261 and 297, two VOCs, arsenic, cadmium, chromium, lead, and mercury detected at concentrations exceeding criteria. Mercury concentrations were below the secondary criteria.	Further Action - Phase II Confirmatory Samples
SWMU 298 1780 Oil/Water Separator No. 3	Oil/water separator associated with SWMU 262. Contains oil, grease, and water.	No compound concentrations exceeded criteria.	No Further Action
SWMU 299 AS114 Above Ground Storage Tank	Used oil AST. Significant staining noted on tank exterior	One VOC, several SVOCs, and six metals-- arsenic, cadmium, chromium, lead, mercury, and silver detected at concentrations exceeding criteria.	Further Action - Phase II Confirmatory Samples
SWMU 300 AS118 Above Ground Storage Tank	Used motor oil AST	Two SVOCs, arsenic and mercury detected at concentrations exceeding criteria. The arsenic and mercury concentrations were below the secondary criteria.	Further Action - Phase II Confirmatory Samples
SWMU 301 AS4115 Above Ground Storage Tank	Two ASTs that contain POLs	Arsenic and mercury detected at concentrations exceeding criteria. Mercury concentrations were below secondary criteria.	Further Action - Phase II Confirmatory Samples
SWMU 302 AS563 Above Ground Storage Tank	AST that contains used engine, hydraulic and transmission oil	The SVOC benzo(a)pyrene and the metal cadmium detected at concentrations exceeding criteria.	Further Action - Phase II Confirmatory Samples
SWMU 303 AS515 Above Ground Storage Tank	Two ASTs that are labeled as "Hydraulic Fluid, Engine and Transmission Oils Only, No Solvents or Other Chemicals"	One VOC, three SVOCs, arsenic and chromium detected at concentrations exceeding criteria.	Further Action - Phase II Confirmatory Samples

TABLE 3-2 (Continued)
PHASE I SWMU INVESTIGATION SUMMARY
BACKGROUND STUDY - CTO-371
MCB, CAMP LEJEUNE, NORTH CAROLINA

SWMU Identification	SWMU Description	Summary of Results	Recommendations
SWMU 304 BA103 Oil/Water Separator	Oil/water separator connected to a drain field	Arsenic detected at concentration exceeding criteria.	Further Action - Phase II Confirmatory Samples
SWMU 305 BB224 Pile	Former location of soil pile which reportedly contained grease and contaminated soil	Arsenic detected at concentration exceeding criteria.	Further Action - Phase II Confirmatory Samples
SWMU 306 FC230 Oil/Water Separator	Oil/water separator associated with vehicle wash area	Silver and mercury detected at concentrations exceeding criteria. Mercury concentrations were below the secondary criteria.	Further Action - Phase II Confirmatory Samples
SWMU 307 G649 Wash Rack	Oil/water separator and vehicle wash rack	Arsenic and mercury detected at concentrations exceeding criteria.	Further Action - Phase II Confirmatory Samples
SWMU 308 GP109 Oil/Water Separator	Oil/water separator associated with a vehicle wash rack	The SVOC bis (2-chloroethyl) ether detected at concentrations exceeding criteria.	Further Action - Phase II Confirmatory Samples
SWMU 309 NH118 Underground Storage Tank	Waste oil UST and AST	Arsenic detected at concentrations exceeding criteria.	Further Action - Phase II Confirmatory Samples
SWMU 310 PT33 Pond Oil/Water Separator	Several earthen impoundments used for dewatering of cooking grease	Arsenic detected at concentrations exceeding the primary criteria but below the secondary criteria.	No Further Action
SWMU 311 S1619 Oil/Water Separator	Oil/water separator associated with a vehicle wash rack	Two VOCs and five metals -- arsenic, cadmium, chromium, lead, and mercury detected at concentrations exceeding criteria. Mercury concentrations were below the secondary criteria.	Further Action - Phase II Confirmatory Samples

TABLE 3-2 (Continued)
PHASE I SWMU INVESTIGATION SUMMARY
BACKGROUND STUDY - CTO-371
MCB, CAMP LEJEUNE, NORTH CAROLINA

SWMU Identification	SWMU Description	Summary of Results	Recommendations
SWMU 312 Oil Water Separator S-1735 (S-1698)	Oil/water separator that receives steam condensate from the Steam Plant (Building 1700)	The SVOC benzo(a)pyrene and the metals arsenic and mercury detected at concentrations exceeding criteria. Mercury concentrations were below the secondary criteria.	Further Action - Phase II Confirmatory Samples
SWMU 313 S1753 Oil/Water Separator	Oil/water separator associated with a vehicle and equipment wash area	Arsenic, mercury and silver detected at concentrations exceeding criteria. Mercury concentrations were below the secondary criteria.	Further Action - Phase II Confirmatory Samples
SWMU 314 SM187 Oil/Water Separator	Oil/water separator associated with a vehicle wash rack	The SVOC benzo(a)pyrene and the metals arsenic and mercury detected at concentrations exceeding criteria. Mercury concentrations were below the secondary criteria.	Further Action - Phase II Confirmatory Samples
SWMU 315 SM269 Oil/Water Separator Near Building M200	Oil/water separator associated with a vehicle wash rack. Unit may have been used for disposal of waste oil	The SVOC pentachlorophenol and three metals -- arsenic, mercury, and silver detected at concentrations exceeding criteria. Mercury concentrations were below the secondary criteria.	Further Action - Phase II Confirmatory Samples
SWMU 316 TC773 Oil/Water Separator	Oil/water separator and vehicle wash rack	The SVOC benzo(a)pyrene and the metal arsenic detected at concentrations exceeding criteria. Arsenic concentrations were below the secondary criteria.	Further Action - Phase II Confirmatory Samples
SWMU 317 TT2453 Release	Area near a used antifreeze AST where a release had reportedly occurred	Arsenic, lead and mercury detected at concentrations exceeding criteria. Mercury concentrations were below the secondary criteria.	Further Action - Phase II Confirmatory Samples

TABLE 3-2 (Continued)
PHASE I SWMU INVESTIGATION SUMMARY
BACKGROUND STUDY - CTO-371
MCB, CAMP LEJEUNE, NORTH CAROLINA

SWMU Identification	SWMU Description	Summary of Results	Recommendations
SWMU 318 AS515 Oil/Water Separator	Oil/water separator and grit chamber associated with a helicopter wash pad	Two VOCs, several SVOCs, and five metals -- arsenic, cadmium, chromium, mercury, and silver detected at concentrations exceeding criteria.	Further Action - Phase II Confirmatory Samples
SWMU 319 Camp Geiger Wastewater Treatment Plant	An AST at the Camp Geiger Wastewater Treatment Plant	Three SVOCs, arsenic and mercury detected at concentrations exceeding criteria. Arsenic concentrations were below the secondary criteria.	Further Action - Phase II Confirmatory Samples
SWMU 336 AS4106 Paint Stripper	Two paint stripping vats.	The floor drains located on either side of the vats contained no sediments. No samples were collected from this SWMU.	Further Action - Phase II Confirmatory Samples
SWMU 337 AS518 Paint Stripper	Two paint stripping vats in an organic stripping room.	Arsenic detected at concentrations exceeding the primary criteria but below the secondary criteria.	No Further Action
SWMU 339 AS4146 Sand Blasting Area	Covered sand blasting area	For soil, one VOC , one SVOC, and arsenic detected at concentrations exceeding criteria. For sediment, four SVOCs and four metals -- cadmium, chromium, lead and silver detected at concentrations exceeding criteria.	Further Action - Phase II Confirmatory Samples

TABLE 3-2 (Continued)
SWMU PHASE I INVESTIGATION SUMMARY
CTO-371
MCB CAMP LEJEUNE, NORTH CAROLINA

Notes:

AST	=	aboveground storage tank
IR	=	Installation Restoration
POL	=	Petroleum, Oil and Lubricants
SVOC	=	semivolatile organic compounds
SWMU	=	Solid Waste Management Unit
UST	=	underground storage tank
VOC	=	volatile organic compound

TABLE 4-1

SUMMARY OF SWMUs FROM CONFIRMATORY STUDY
WITH ASSOCIATED AREA OF CONCERN
BACKGROUND STUDY - CTO- 0371
MCB, CAMP LEJEUNE, NORTH CAROLINA

SWMU Number*	SWMU Name	Area of Concern
2	SWMU 2 1700 Pond A	5
5	SWMU 5 575 Rack	7
43	SWMU 43 Pest Control Shop (IR Site No. 11)	5
46	SWMU 46 Montford Point Dump Site (IR Site No. 15)	3
53	SWMU 53 Coal Storage Area (IR Site No. 26)	5
253	SWMU 253 1205 Above Ground Storage Tank	6
254	SWMU 254 1408 Dumpster	5
255	SWMU 255 1502 Oil/Water Separator No. 1	5
256	SWMU 256 1700 Oil/Water Separator No. 1	5
257	SWMU 257 1700 Oil/Water Separator No. 2	5
258	SWMU 258 S1745 Oil/Water Separator	5
260	SWMU 260 1780 Oil/Water Separator No. 1	7

TABLE 4-1 (Continued)

SUMMARY OF SWMUs FROM CONFIRMATORY STUDY
BACKGROUND STUDY - CTO– 0371
MCB, CAMP LEJEUNE, NORTH CAROLINA

SWMU Number[a]	SWMU Name	Area of Concern
261	SWMU 261 1780 Underground Storage Tank No. 1	7
262	SWMU 262 1780 Underground Storage Tank No. 2	7
264	SWMU 264 2611 Container	4
265	SWMU 265 2615 Oil/Water Separator	4
269	SWMU 269 816 Oil/Water Separator	9
272	SWMU 272 AS137 Oil/Water Separator	2
273	SWMU 273 BA128/BA105 Dumpster	11
275	SWMU 275 BB48 Dumpster	10
276	SWMU 276 BB49 Dumpster	10
277	SWMU 277 FC120 Oil/Water Separator	9
279	SWMU 279 FC200 Oil/Water Separator	8
284	SWMU 284 S947 Container	6
285	SWMU 285 S947 Oil/Water Separator	6
286	SWMU 286 S947 Pile	6

TABLE 4-1 (Continued)

SUMMARY OF SWMUs FROM CONFIRMATORY STUDY
BACKGROUND STUDY - CTO– 0371
MCB, CAMP LEJEUNE, NORTH CAROLINA

SWMU Number	SWMU Name	Area of Concern
291	SWMU 291 034 Ditch	7
292	SWMU 292 1106/1107 Above Ground Storage Tank	6
293	SWMU 293 1106/1107 Oil/Water Separator	6
294	SWMU 294 1203 Oil/Water Separator	6
295	SWMU 295 1601 Above Ground Storage Tank	5
296	SWMU 296 1700 Basin B	5
297	SWMU 297 1780 Oil/Water Separator No. 2	7
298	SWMU 298 1780 Oil/Water Separator No. 3	7
299	SWMU 299 AS114 Above Ground Storage Tank	2
300	SWMU 300 AS118 Above Ground Storage Tank	2
301	SWMU 301 AS4115 Above Ground Storage Tank	2
302	SWMU 302 AS563 Above Ground Storage Tank	2
303	SWMU 303 AS515 Above Ground Storage Tank	2

TABLE 4-1 (Continued)

SUMMARY OF SWMUs FROM CONFIRMATORY STUDY
BACKGROUND STUDY - CTO- 0371
MCB, CAMP LEJEUNE, NORTH CAROLINA

SWMU Number	SWMU Name	Area of Concern
304	SWMU 304 BA103 Oil/Water Separator	11
305	SWMU 305 BB224 Pile	10
306	SWMU 306 FC230 Oil/Water Separator	9
307	SWMU 307 G649 Wash Rack	1
308	SWMU 308 GP109 Oil/Water Separator	9
309	SWMU 309 NH118 Underground Storage Tank	4
310	SWMU 310 PT33 Pond Oil/Water Separator	6
311	SWMU 311 S1619 Oil/Water Separator	5
312	SWMU 312 Oil Water Separator S-1735 (S-1698)	5
313	SWMU 313 S1753 Oil/Water Separator	5
314	SWMU 314 SM187 Oil/Water Separator	3
315	SWMU 315 SM269 Oil/Water Separator Near Building M200	3
316	SWMU 316 TC773 Oil/Water Separator	1
317	SWMU 317 TT2453 Release	4
318	SWMU 318 AS515 Oil/Water Separator	2
319	SWMU 319 Camp Geiger Wastewater Treatment	1

TABLE 4-1 (Continued)

SUMMARY OF SWMUs FROM CONFIRMATORY STUDY
BACKGROUND STUDY - CTO– 0371
MCB, CAMP LEJEUNE, NORTH CAROLINA

SWMU Number(a)	SWMU Name	Area of Concern
	Plant	
336	SWMU 336 AS4106 Paint Stripper	2
337	SWMU 337 AS518 Paint Stripper	2
339	SWMU 339 AS4146 Sand Blasting Area	2

Notes:

(a) SWMU = solid waste management unit
(b) VOA = volatile organic analysis
SVOA = semivolatile organic analysis
PCBs = polychlorinated biphenyls
RCRA = Resource Conservation and Recovery Act

TABLE 4-2

SUMMARY OF AREAS OF CONCERN
BACKGROUND STUDY – CTO-0371
MARINE CORPS BASE
CAMP LEJEUNE, NORTH CAROLINA

Area of Concern	SWMUs Associated with AOC	Number of Sampling Locations
1	307, 316, 319	15
2	272, 299, 300, 301, 302, 303, 318, 336, 337, 339	19
3	46, 314, 315	14
4	264, 265, 309, 317	14
5	2, 43, 53, 245, 254, 255, 256, 257, 258, 295, 296, 311, 312, 313	17
6	253, 284, 285, 286, 292, 293, 294, 310	14
7	5, 260, 261, 262, 291, 297, 298	16
8	279, 280, 283	14
9	269, 277, 306, 308	14
10	275, 276, 305	14
11	273, 304	13

TABLE 4-3

SUMMARY OF SWMUs REQUIRING f_{oc} ANALYSIS
BACKGROUND STUDY - CTO-0371
MARINE CORPS BASE
CAMP LEJEUNE, NORTH CAROLINA

SWMU Number	Rationale for Additional Analyses	Sampling Locations
43	Pesticides and Semivolatiles	IS01 IS02 IS03 IS04
89	Volatiles and Semivolatiles	IS01 IS02 IS03
254	Semivolatiles	SS01 SS02
255	Semivolatiles	SS01
256	Semivolatiles	IS02 IS03
258	Volatiles	IS02 IS05
261/297	Volatiles and Inorganics	261-IS02
264	Semivolatiles and Pesticides	IS01 SS01
272	Volatiles and Semivolatiles	IS01 IS02 IS03 IS04
285	Volatiles and Semivolatiles	IS03
299	Volatiles and Semivolatiles	IS01 IS02 IS03 IS04
300	Semivolatiles	IS03
302	Semivolatiles	IS03
303	Volatiles and Semivolatiles	IS04
308	Semivolatiles	IS04
315	Semivolatiles	IS03
316	Semivolatiles	IS01 IS02 IS03
318	Volatiles and Semivolatiles	IS01 SS01
319	Semivolatiles	IS01
	Total Sampling Locations	**37**

Note:

1. Sampling locations are from the Phase I Confirmatory Sampling Study.
2. f_{oc} (fraction of organic carbon) is used in the calculation for K_d (Partition Coefficient) which is used in the establishment of screening values for organics in soils.

FIGURES

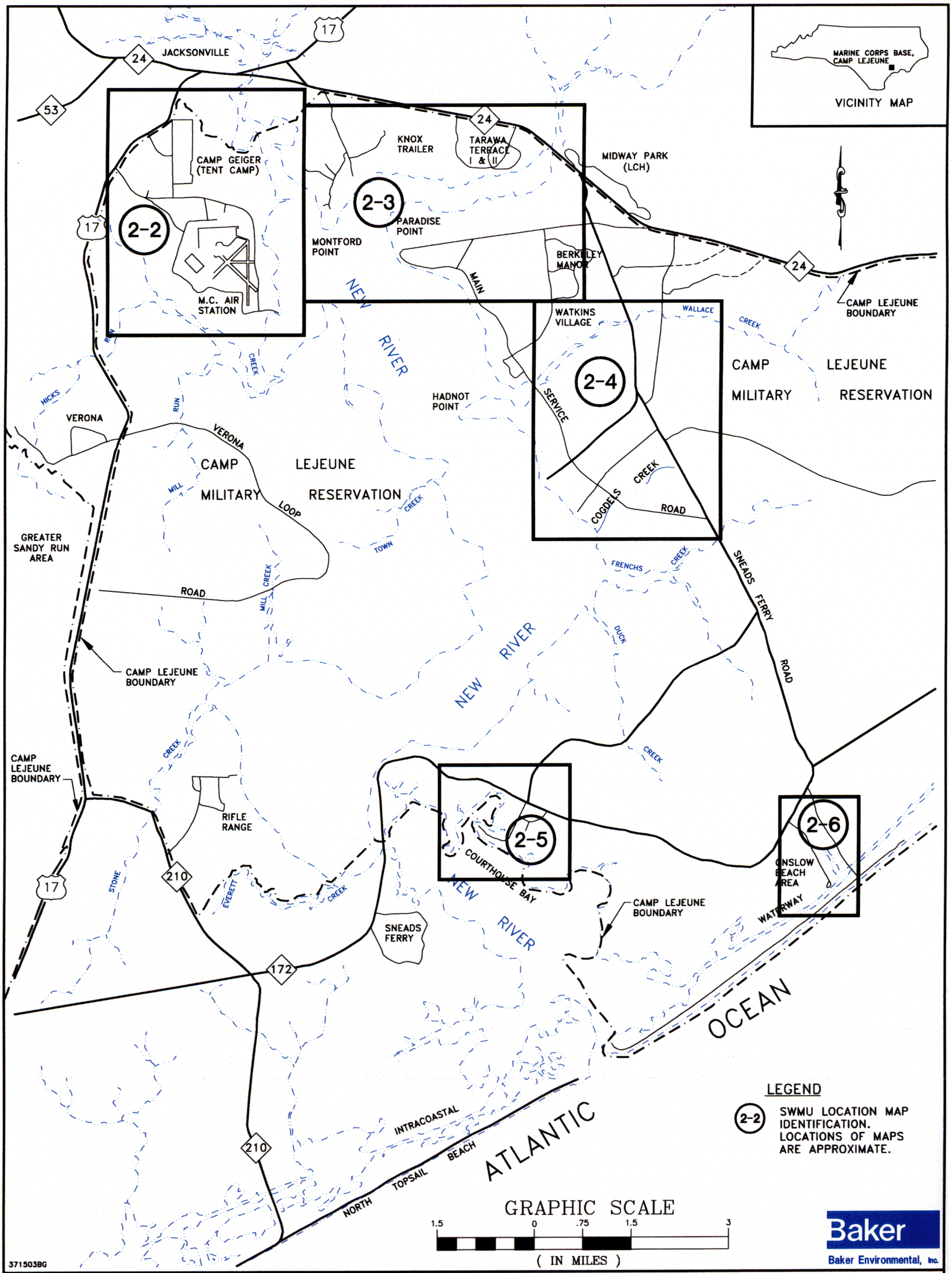
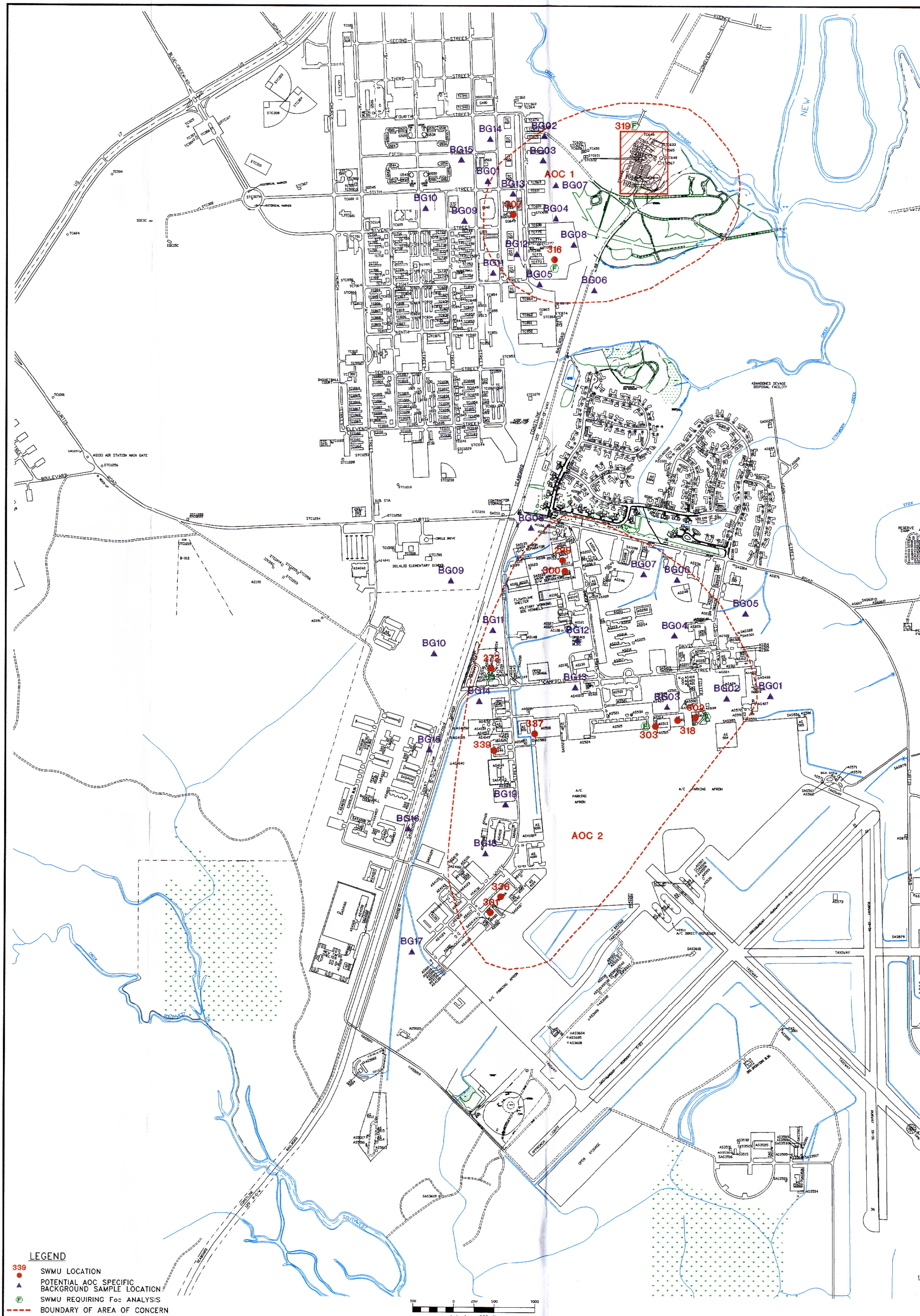
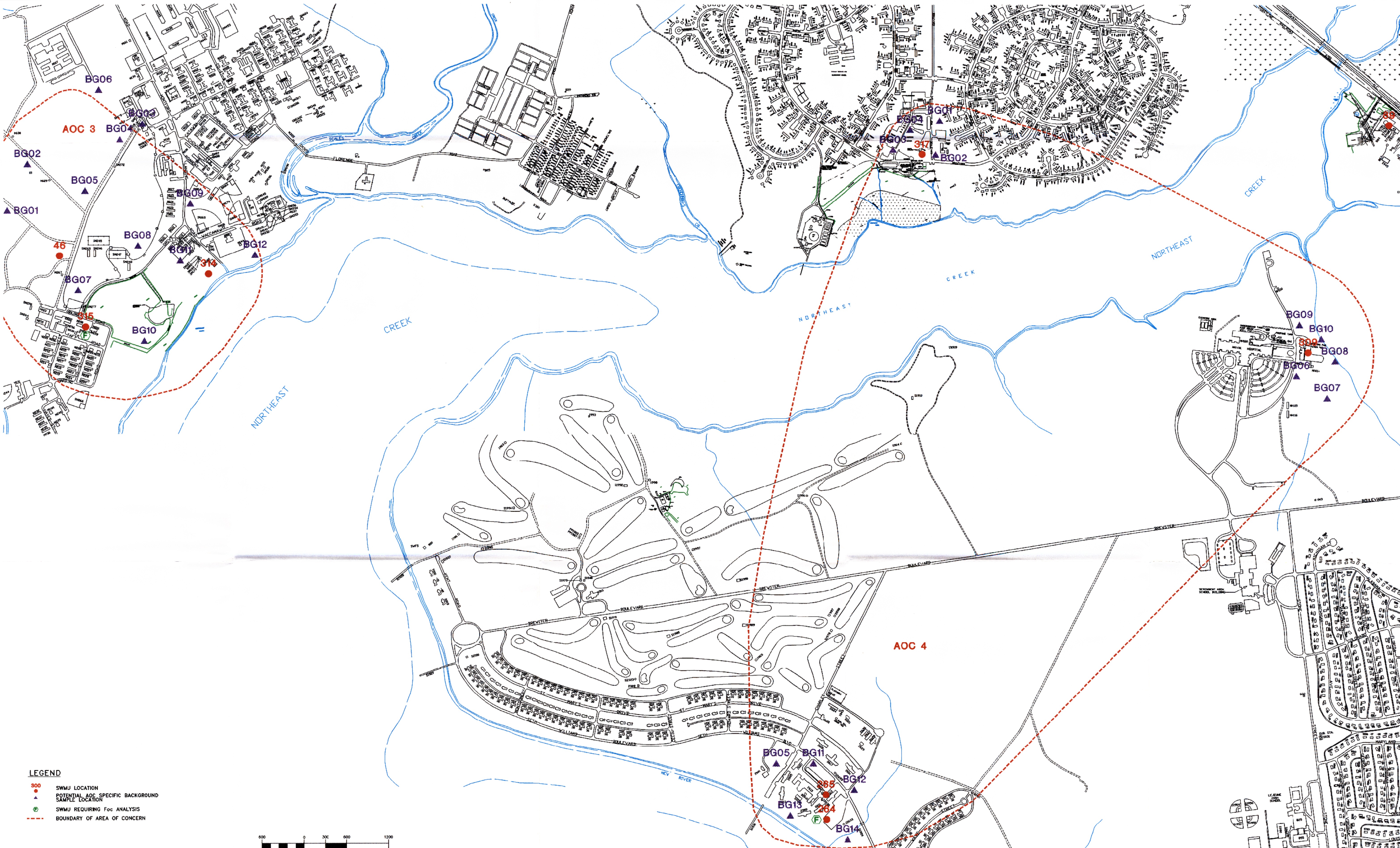


FIGURE 2-1
MCB CAMP LEJEUNE LOCATION/INDEX MAP
BACKGROUND STUDY SAMPLE STRATEGY PLAN
CTO - 0371

MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA



LEGEND	DRAWN WJH REVIEWED JSC S.O.# 62470-371 CADD# 371505BG	NORTH	BACKGROUND STUDY SAMPLE STRATEGY PLAN MARINE CORPS BASE, CAMP LEJEUNE NORTH CAROLINA BAKER ENVIRONMENTAL, Inc. Coraopolis, Pennsylvania	Baker Baker Environmental, Inc.	CAMP GEIGER/MCAS AREA SWMU LOCATION MAP SCALE 1" = 500' DATE MARCH 2000	FIGURE No. 2-2



REVISIONS			NORTH
	DRAWN	WJH	
	REVIEWED	JSC	
	S.O.#	62470-371	
	CADD#	371501BG	

BACKGROUND STUDY SAMPLE STRATEGY PLAN
MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA

BAKER ENVIRONMENTAL, Inc.
Coraopolis, Pennsylvania

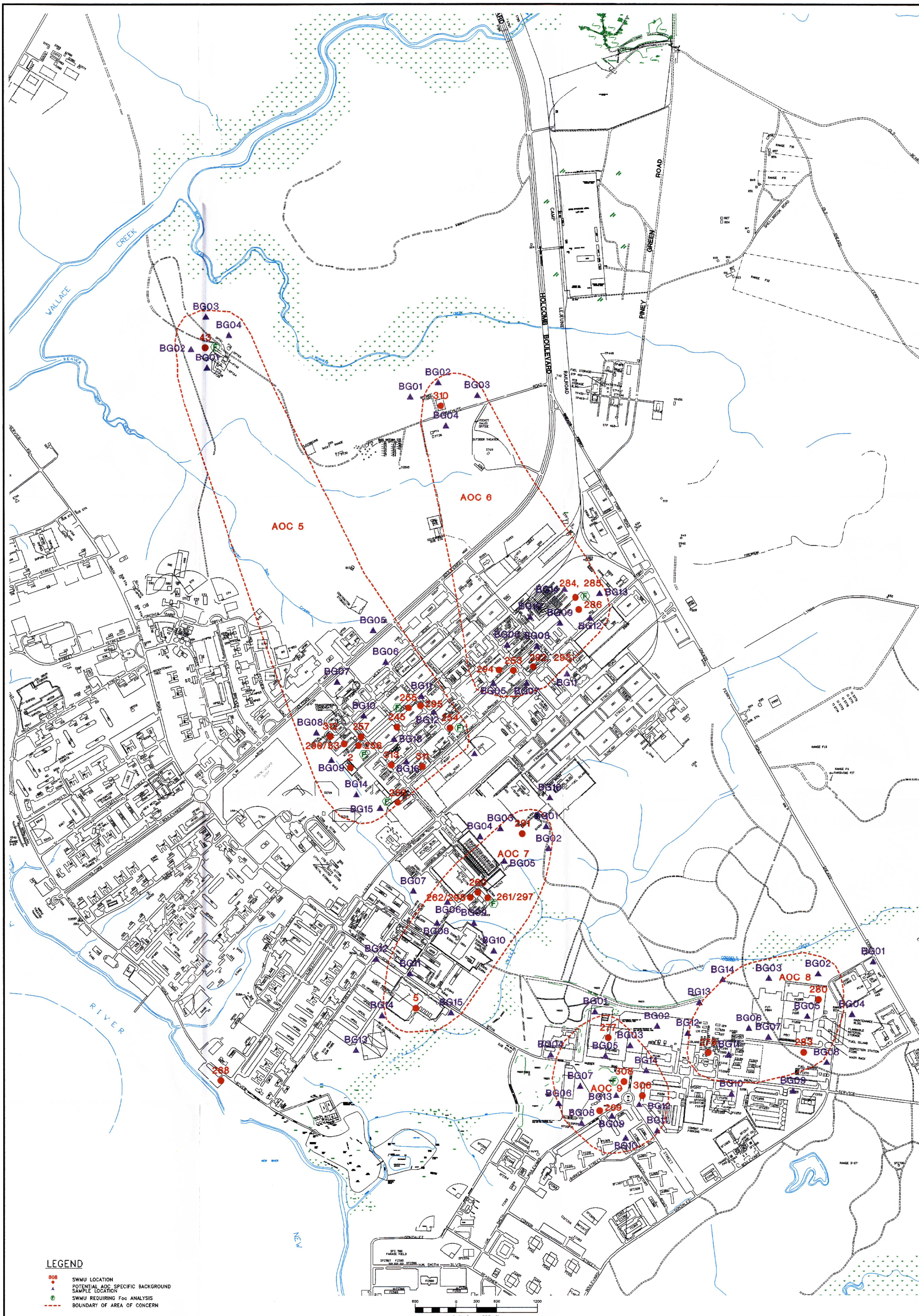
Baker
Baker Environmental, Inc.

TARRAWA TERRACE/MONTFORD POINT AREA
SWMU LOCATION MAP

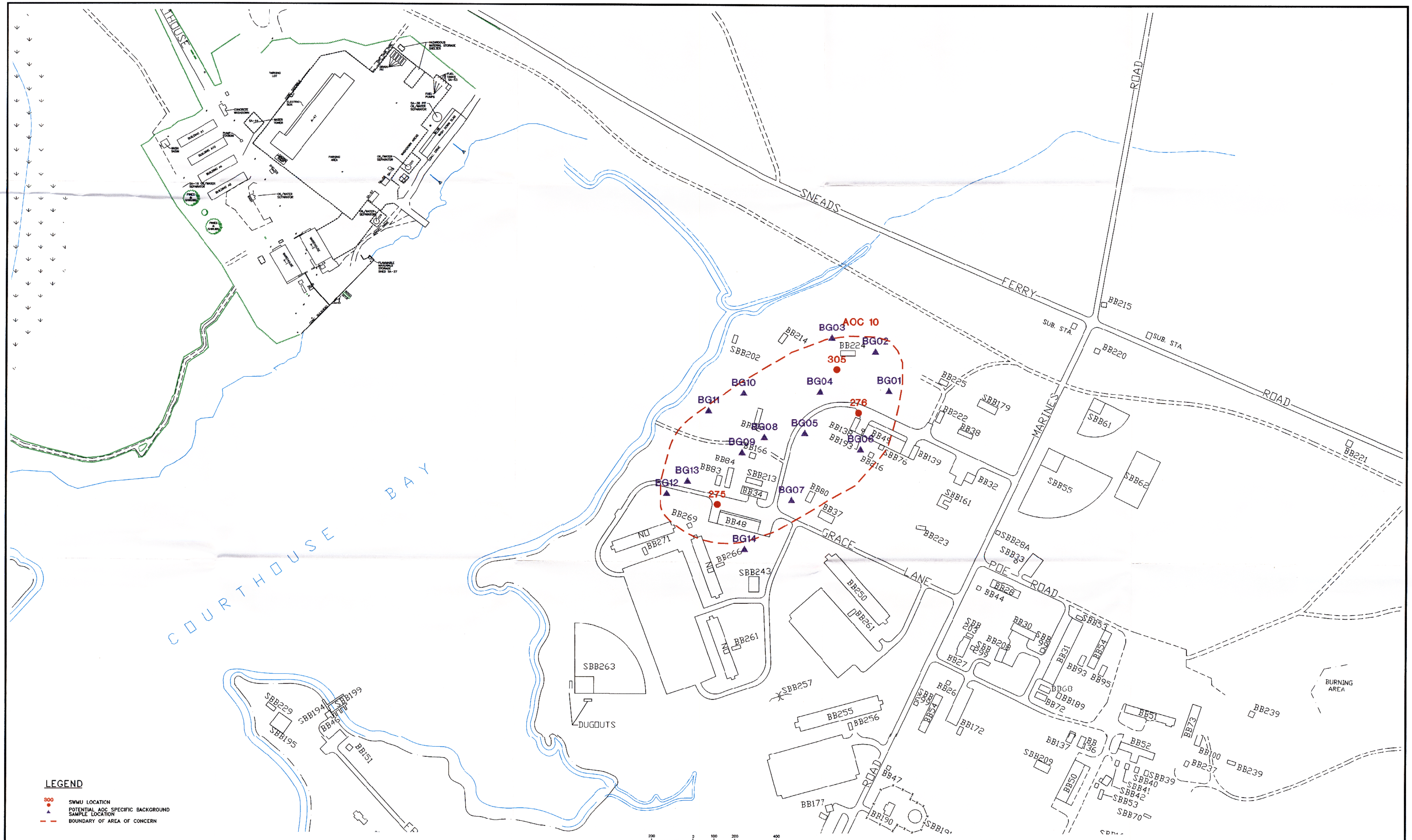
SCALE 1" = 600'

DATE MARCH 2000

FIGURE No.
2-3



LEGEND	DRAWN WJH REVIEWED JSC S.O.# 62470-371 CADD# 371506BG	NORTH	BACKGROUND STUDY SAMPLE STRATEGY PLAN MARINE CORPS BASE, CAMP LEJEUNE NORTH CAROLINA BAKER ENVIRONMENTAL, Inc. Coraopolis, Pennsylvania	Baker Baker Environmental, Inc.	HADNOT POINT AREA SWMU LOCATION MAP SCALE 1" = 600' DATE MARCH 2000	FIGURE No. 2-4



DRAWN	WJH
REVIEWED	JSC
S.O.#	62470-371
CADD#	371500BG

REVISIONS

NORTH

BACKGROUND STUDY SAMPLE STRATEGY PLAN
MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA

BAKER ENVIRONMENTAL, Inc.
Coraopolis, Pennsylvania

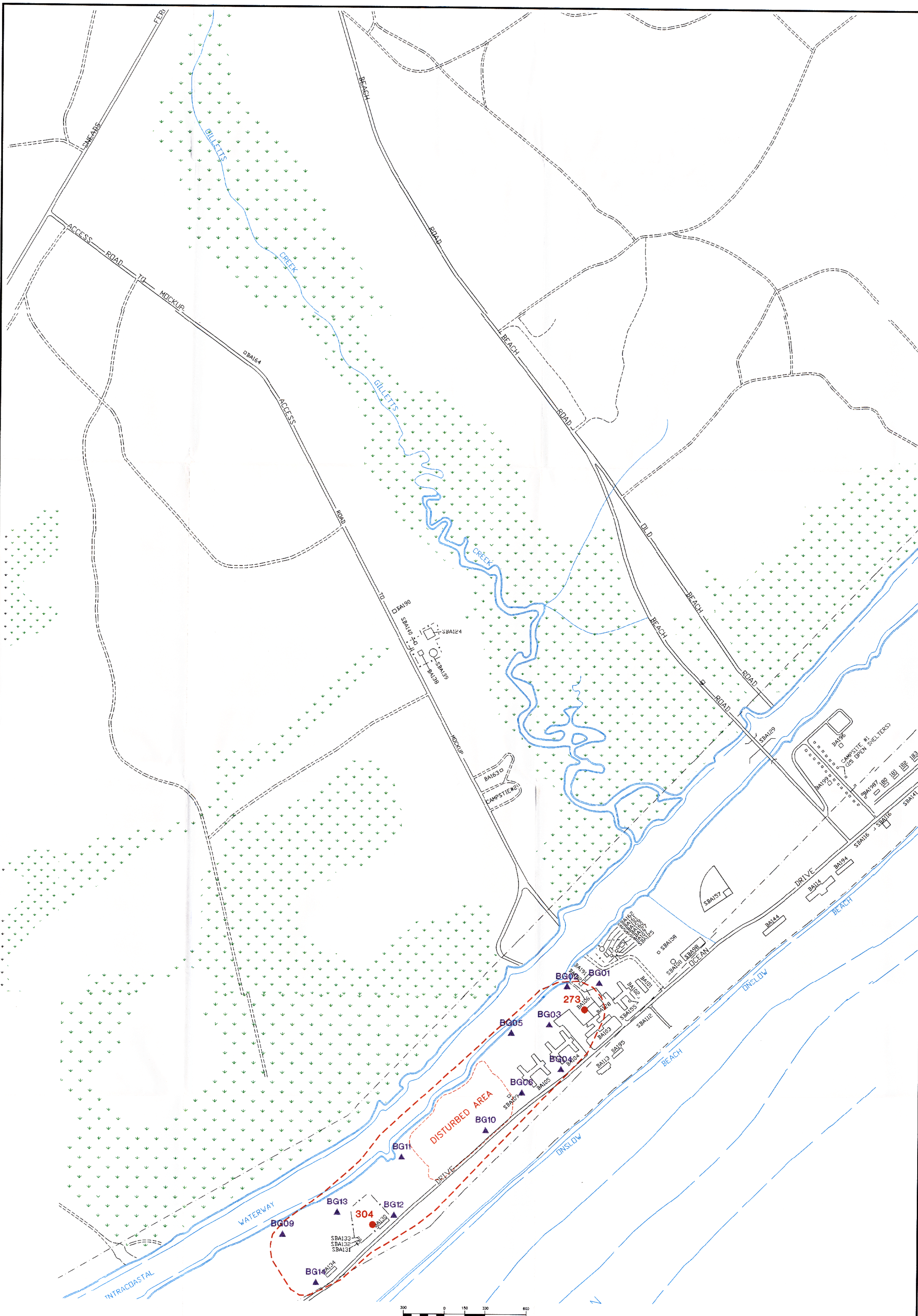
Baker
Baker Environmental, Inc.

COURTHOUSE BAY AREA
SWMU LOCATION MAP

SCALE 1"= 200'

DATE MARCH 2000

FIGURE No.
2-5



LEGEND	
300 ●	SWMU LOCATION
▲	POTENTIAL AOC SPECIFIC BACKGROUND SAMPLE LOCATION
- - -	BOUNDARY OF AREA OF CONCERN

DRAWN WJH
REVIEWED JSC
S.O.# 62470-371
CADD# 371502BG

NORTH

BACKGROUND STUDY SAMPLE STRATEGY PLAN
MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA

BAKER ENVIRONMENTAL, Inc.
Coraopolis, Pennsylvania

Baker
Baker Environmental, Inc.

BEACH AREA
SWMU LOCATION MAP

SCALE 1"= 300'
DATE MARCH 2000

FIGURE No.
2-6

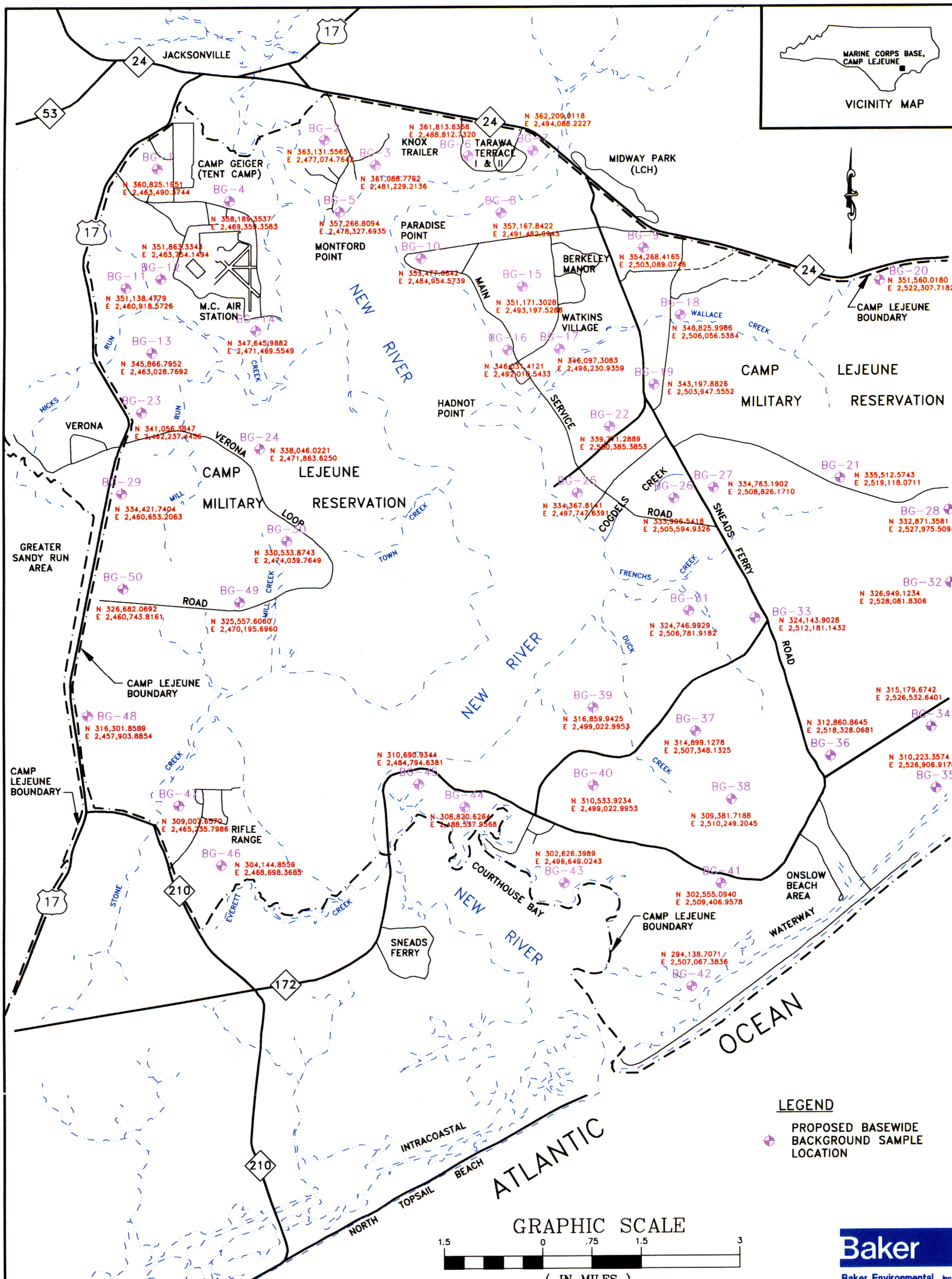


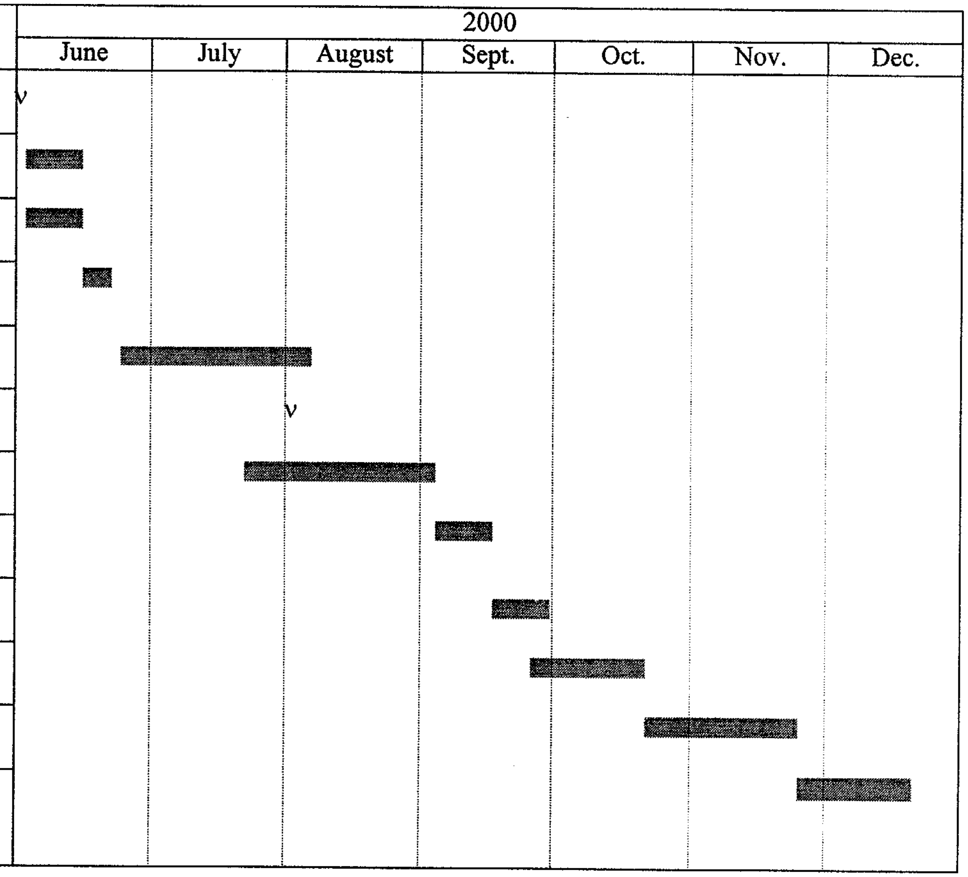
FIGURE 4-1
MCB CAMP LEJEUNE PROPOSED BASEWIDE BACKGROUND SAMPLE LOCATION MAP
BACKGROUND STUDY SAMPLE STRATEGY PLAN
CTO - 0371

MARINE CORPS BASE, CAMP LEJEUNE
NORTH CAROLINA

FIGURE 6-1

PROPOSED SCHEDULE FOR THE BACKGROUND STUDY
BACKGROUND STUDY SAMPLE STRATEGY PLAN - CTO-371
MCB, CAMP LEJEUNE, NORTH CAROLINA

Task Name	Duration
Receive State's Concurrence of the Proposed Background Study (SSP)	1 eday
Submit the Final Background Study SSP	14 edays
Procurement of Subcontractors	14 edays
Mobilize to the Field	7 edays
Conduct Field Investigation	40 edays
Demobilize from Field	1 eday
Receive Analytical Results	40 edays
Receive Validated Data	14 edays
Statistical Evaluation of Data	14 edays
Submit Draft Background Study Report	28 edays
Receive Comments on Draft Report	30 edays
Submit Final Report and Response to Comments	28 edays



Notes:

eday = elapsed days
Task =
Milestone = ν

APPENDIX A
CLOSURE PLAN REVIEW GUIDANCE FOR RCRA FACILITIES

3.12 Guidance for Statistical Evaluation of Hazardous Waste Constituent Levels in Soils

3.12.1 Introduction

When a clean closure of a hazardous waste management unit (unit) includes remediation of affected soil to the site specific background concentrations, the determination whether the soil has been successfully remediated always relies on some kind of statistical inference. In order to assist closure plan reviewers to decide whether the background-based remediation standards (BRS) were established properly and if the statistical analyses were applied correctly, some commonly used statistical procedures are discussed in the following text. In general, these procedures allow for comparison between selected observations in such a way that the result of comparison can be obtained with a specified (required) level of confidence (or significance).

In order to conduct a background-based clean closure process (closure), it is necessary to establish a BRS for each constituent of concern. For that purpose, an adequate number of background soil samples must be collected. While this number depends on many factors, the Ohio EPA believes that it <u>should not be less than twelve (12)</u>. The concentrations of a constituent in the soil samples (determined through the laboratory analysis) form <u>one</u> "statistical sample" of all background concentrations - a "background data set". In addition, to complete (and certify) a closure, soil samples should be collected from under and/or around the unit (the affected area now assumed to be remediated) to prove that the constituent concentrations have been "sufficiently" lowered. These concentrations are data points which form a "confirmation data set". Unless <u>all</u> confirmation concentrations are below the BRS, a statistical test is necessary to demonstrate (in an objective manner) if a "sufficient" level of soil remediation has been attained. Depending on whether data is, or is not, normally distributed (or can/cannot be normalized with a transformation common to both data sets), two types of statistical methods are used. They are respectively called "parametric" and "nonparametric" methods. For the purpose of this guidance document, the more common parametric approach will be discussed in some detail, while a reference will be made to nonparametric methods whenever appropriate.

3.12.2 DETERMINATION OF THE NUMBER OF SAMPLES

Due to practical reasons and constraints, statistical analyses are frequently conducted on a limited number of observations. This limited number of observations represents a (statistical) sample (not to be confused with a "soil sample") extracted from a much larger group of values (called "population") in an attempt to estimate some statistical parameter(s) (such as a mean value of metal concentrations, for instance), or to conduct a statistical test, while staying within economical and technical limits. If the entire population could be taken into account, a statistical estimate would reflect a <u>"true"</u> value. Any lesser number of observations will probably introduce an error. In other words, how close and how reliably will a statistical parameter represent the truth, or how correct a conclusion drawn from a particular statistical test will be, depends largely on the number of observations that were chosen to represent the population. Determination of a <u>smallest</u> number of observations (smallest sample size) that will still allow a certain satisfactory level of confidence in a statistical evaluation, is a common problem. Unfortunately, it does not have a straightforward answer. The following are some of the reasons:

- Different statistical methods for testing hypotheses, or for determination of estimators (mean, variance, quantiles, etc.), require a different number of observations (data points) in order to achieve desired accuracy and level of confidence (i.e., the kind of methods involved must be known up-front);

- Desired accuracy and confidence level have to be predetermined;

- An assumption about normality of data distribution has to be made before the data is actually collected;

- A guess has to be made about dispersion (variability) of data.

It is obvious that the above requirements lead to a somewhat arbitrary determination of a smallest acceptable number of observations. To facilitate the initial choice of a (statistical) sample size for the purpose of establishing background based remediation standards for soils, Ohio EPA recommends a minimum of 12 (twelve) soil samples to be collected from an appropriate soil type (as described under "Requirements for Background Soil Sampling and Data Management" Section 3.11.1.1). In statistical terms, these 12 data points allow for determination of a mean value with 95% probability that it will not exceed a true (population) mean by 50%. In other words, if soil sampling, analysis and the mean value calculations were done repeatedly, many times in the same manner, a chance of making an estimate of a mean value 50% greater than the true mean is only 5%. If, for example, a true mean of a metal concentration in soil is 145 mg/kg, then the estimated mean would be less than 217.5 mg/kg (true mean + 50% of the true mean) 95% of the time. This is correct only under the assumption that the soil samples (not correlated over time and space) were collected through a simple random sampling process, that the results of laboratory analysis (data) are normally distributed, and that the coefficient of variation (the ratio between the standard deviation and the mean of the collected data) is within 95%. (For more detailed explanation, see Gilbert, Chapter 4.)

The above discussion shows that the recommended minimum of 12 (twelve) soil samples offers somewhat limited accuracy in estimating the mean value (and may be inadequate for some other type of statistical inference). If a more accurate estimate of the mean concentration of a constituent in a given soil is required, or if any other requirement (statistical method) so dictates, the necessary number of background soil samples has to be increased.

It is also important to mention that all 12 (twelve) soil samples have to be valid (i.e., usable). To avoid additional sampling in case something goes wrong (lab error, outlier, etc.), it is considered a good practice to collect more than 12 soil samples initially.

Various methods on how to determine an appropriate (necessary) number of observations are presented in many statistical textbooks, papers and guidance documents (some of which are referenced at the end of this section).

3.12.3 Data Comparison

Under the assumption that the background and confirmation data are normally distributed (which needs to be demonstrated through appropriate tests for normality, i.e. probability plots, box and whiskers plots, Shapiro-Wilk test, and/or Kolmogorov-Smirnov test with Lilliefors critical values) a BRS is defined as a **mean value plus two standard deviations of the background data (i.e., concentrations).**

So defined, BRS represents the 97.72th percentile (or the 0.9772 quantile - quantiles are percentiles expressed as a fraction rather than percents) of the background distribution. In that case, the soil can be declared successfully remediated (for the metal of concern) when the 95% upper confidence limit for the mean of the confirmation data (which also has to be normally distributed for this purpose) is significantly smaller than the BRS. This can be demonstrated through a one sided 95% confidence (i.e., 0.05 significance) level t test. (If all confirmation data points are below BRS, there is no need for any formal statistical test.)

$$\frac{\overline{Y} - BRS}{S_y / \sqrt{m}} < -t_{m-1,\,0.95}$$

or

$$\overline{Y} + t_{m-1,\,0.95} \times (S_y / \sqrt{m}) < BRS$$

where:

$\overline{Y}$ - mean of confirmation data

S_y - standard deviation of confirmation data,

m - number of confirmation samples, and

$t_{m-1,\,0.95}$ - 0.95th quantile of the t distribution with m-1 degrees of freedom

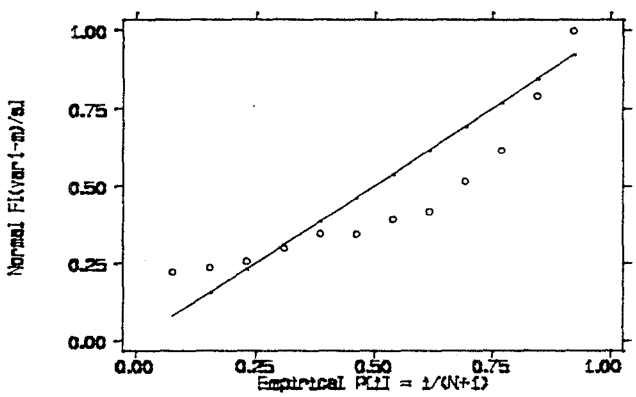
NOTE: When the background and confirmation data sets (both or either one) are not normal, and cannot be normalized, an appropriate nonparametric test (such as: Wilcox on Rank-Sum Test, test of proportions, etc.) should be utilized to prove that the soil has been satisfactorily remediated.

3.12.4 Test for Normality

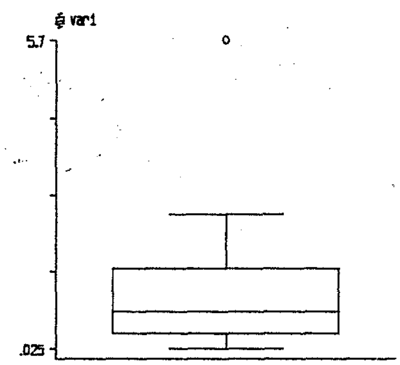
In order to correctly use a t test to demonstrate that the remaining contaminant concentrations do not significantly exceed the BRS, the background and confirmation data must be normally distributed, or transformed to normality using the same transformation. The demonstration of normality should be made graphically (through probability plots and box plots) and through either the Shapiro-Wilk test (also known as the *W*-test), or the Kolmogorov-Smirnov test with Lilliefors critical values. An explanation on how to perform the Shapiro-Wilk and Kolmogorov-Smirnov tests can be found in *Practical Nonparametric Statistics, 2nd Edition, W.J. Conover, 1980 (John Wiley & Sons); and Statistical Methods for Environmental Pollution Monitoring, R.O. Gilbert, 1987 (Van Nostrand Reinhold).*

As an example for graphical determination of normality, the data can be plotted as shown below;

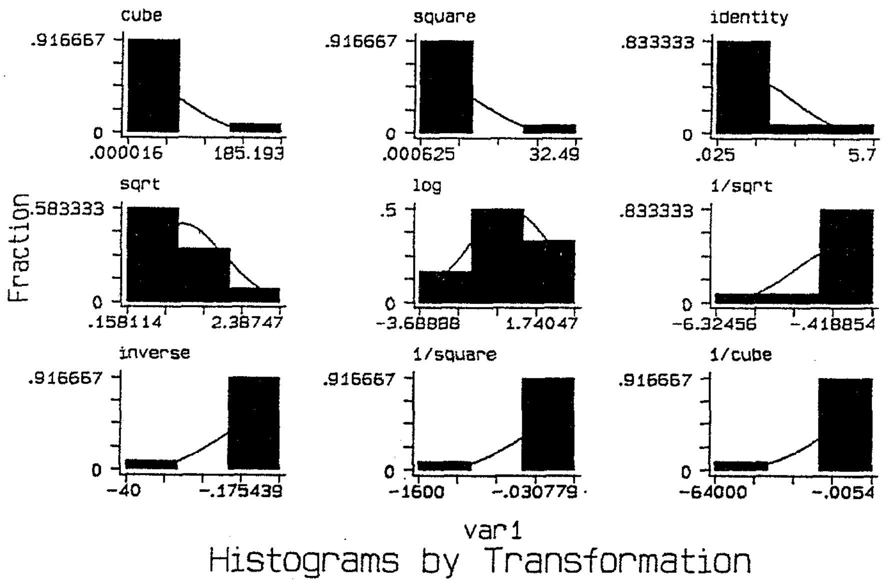
Normal Probability Plot



Box Plot

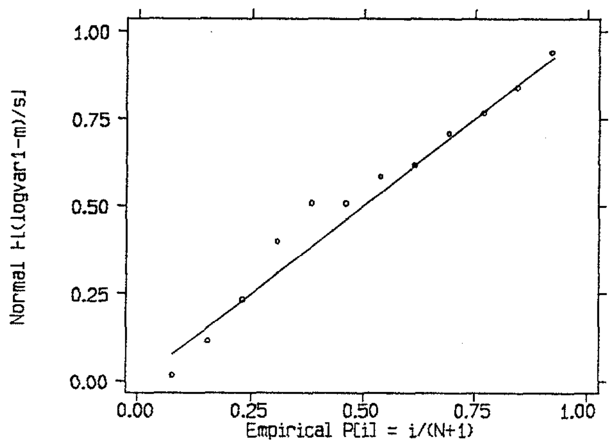


The graphs in this example tend to indicate that the data distribution is not normal. In the case of the probability plot graph, the closer the data points are to the line defining normality, the more likely the data are normally distributed. With the box plot graph, the more symmetrical the plot, the closer to normality the data distribution is. In order to proceed with the statistical analysis, the data set needs to be transformed to normality. Log or power transformations will often make a data set normally distributed. Some computer programs, as shown below, allow for a graphical comparison of several different transformations:

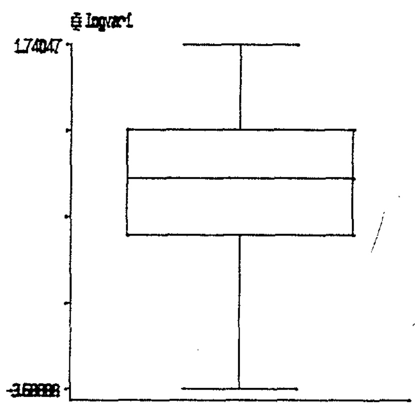


The graphs indicate that (in this case) a log transformation may be the best way to normalize the data. After transforming the data, a check with a probability plot and a box plot can be made to verify this indication.

Normal Probability Plot



Box Plot



A final check for normality should be made through the Shapiro-Wilk test, and/or Kolmogorov-Smirnov test with Lilliefors critical values.

It is important to note that, in order to conduct a t-test, the same kind of transformation must be applied to <u>both</u>, the background data set and the confirmation data set. In other words, to compare the 95% upper confidence limit for the mean of the confirmation data in the transformed scale, the remediation standard must be calculated from the background data set being transformed in the same manner.

If the data sets cannot be transformed to normality, an alternative method (one that does not rely on normality) must be used to prove that the soil has been successfully remediated. The two generally recommended (nonparametric) methods are the Wilcoxon Rank-Sum Test, and the Test of Proportions.

3.12.5 Test for Outliers

Prior to proceeding with statistical analysis, i.e., establishing a BRS from a normally distributed raw, or normalized (transformed) <u>background data</u>, a test for outliers should be conducted. <u>This test is not required for the confirmation data set, but may be used for the screening purposes.</u> Since, in this case, a discovery of an elevated concentration (above the BRS) usually indicates an incomplete remediation, additional <u>soil</u> removal (or treatment) consequently eliminates the outstanding concentration. One, or few <u>slightly</u> elevated concentrations in a confirmation data set may not necessarily require additional soil remediation - if an appropriate statistical test (such as t test) shows that the BRS has not been significantly exceeded. The following equations (Hoaglin et al, 1983) are used to determine whether there is statistical evidence that a background observation (constituent concentration) appears extreme and therefore does not fit the distribution of the rest of the data:

Upper cutoff = upper quartile + 1.5 (interquartile range) **Equation 1**

Lower cutoff = lower quartile - 1.5 (interquartile range) **Equation 2**

where:

Upper quartile (Q_{75} or Q3) equals an observation in the background data set which divides the data so that 25% of the data are greater than Q3 and 75% of the data are less than or equal to Q3;

Lower quartile (Q_{25} or Q1) equals an observation in the background data set which divides the data so that 75% of the data are greater than Q1 and 25% of the data are less than or equal to Q1; and

Interquartile range (IQR) equals the difference between the upper quartile and the lower quartile (i.e., IQR = Q3 - Q1).

Example for <u>even</u> number of background data:

Given the following data set consisting of twelve data points,

1.3 0.8 0.6 0.2 0.1 0.025

0.9	2.5	0.6	0.4	1.7	5.7

the first step is to order the data from least to greatest:

(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)
0.025	0.1	0.2	0.4	0.6	0.6	0.8	0.9	1.3	1.7	2.5	5.7

For an even number of data points, the quartiles are determined by splitting the ordered data set twice equally (i.e., into fourths). The quartiles are found at the splits and can be adequately estimated by averaging the data points on either side of the split. Using the above data set, Q1 falls between the 3rd and 4th observation and is therefore calculated as:

$$(0.2 + 0.4) / 2 = 0.3$$

Similarly, Q3 falls between the 9th and 10th observation and can be calculated as:

$$(1.3 + 1.7) / 2 = 1.5$$

This can be demonstrated visually as follows:

			Q1				(Q2 or median)				**Q3**			
(1)	(2)	(3)	|	(4)	(5)	(6)	|	(7)	(8)	(9)	|	(10)	(11)	(12)
0.025	0.1	0.2		0.4	0.6	0.6		0.8	0.9	1.3		1.7	2.5	5.7
			|				|				|			
			0.3				(0.7)				**1.5**			

After calculating the quartiles, the next step is to calculate the interquartile range (IQR), or the difference between Q3 and Q1:

$$IQR = Q3 - Q1, \text{ i.e.}$$

$$IQR = 1.5 - 0.3 = 1.2$$

The final step is to calculate the Upper and Lower cutoffs as defined by the Equations 1 and 2 above:

$$\text{Upper cutoff} = 1.5 + 1.5(1.2) = 3.3$$

$$\text{Lower cutoff} = 0.3 - 1.5(1.2) = -1.5$$

(or 0, since a negative Lower cutoff does not make sense when data represent constituent concentrations).

In this case, only one observation is not in the range between 0 and 3.3 (i.e., 5.7, or the twelfth observation). Data points not falling between the upper and lower cutoffs should be reviewed to determine whether evidence exists to suggest that these observations are not representative of the background population. The reviewer should direct the facility (entity responsible for conducting closure) to check such data for sampling and laboratory errors, field evidence of waste materials at the sampling locations, and other plausible causes. Where sufficient evidence indicates that an observation does not truly represent concentrations found in background soil, a substitute observation must be provided. If no specific error can be documented, the observation should be retained in the data set.

Example for odd number of background data:

For odd numbered data sets, the lower quartile (Q1) can be found by multiplying the number of observations (n) by 0.25, and then rounding the result to the next largest integer. The resulting number indicates the observation which corresponds to Q1. Similarly, Q3 can be found by multiplying n by 0.75, and rounding to the next larger integer. This number refers to the observation which corresponds to Q3. For example, with the following data set (where n = 13):

(1)	(2)	(3)	(4)	(5)	(6)	(7)
0.1	0.2	0.4	0.6	0.6	0.8	0.9
(8)	(9)	(10)	(11)	(12)	(13)	
1.3	1.7	1.8	2.1	2.5	5.7	

For Q1:

$$0.25 \times 13 = 3.25;\ \text{rounded up} = 4$$

So, Q1 is the 4th observation or 0.6.

Likewise for Q3:

$$0.75 \times 13 = 9.75;\ \text{rounded up} = 10$$

So, Q3 is the 10th observation or 1.8.

Q2 (median) is simply the value in the middle - 7th observation or 0.9.

The rest remains the same as in the previous example for even number of data.

If there are no outliers, statistical analysis may proceed.

If outlier are found, their origin must be investigated (as previously explained) before proceeding with statistical analysis.

3.12.5.1 Outlier Screening Considerations

Availability of some pertinent information on the subject of interest is a prerequisite for conducting statistical analysis. This information is usually contained in a form of a data set generated from a series of observations. Only when these observations are made in accordance with some predetermined rule and followed by a careful data screening process, will the conclusions from statistical analysis be valid. If data do not represent the truth, the results will be more or less irrelevant, no matter how much sophistication was incorporated into the analysis.

One of the reasons why statistical analysis may not render a correct result is the presence of "outliers" in a data set. By some definitions, an outlier is "an observation which appears to be inconsistent with the remainder of the data set" (Barnett and Lewis, 1984), or "an observation which deviates so much from other observations as to arouse suspicions that it was generated by a different mechanism" (Hawkins, 1980). While these definitions provide a good qualitative description of outliers, some formal test is still required to detect their existence within a data set. Due to a relatively long history of this problem, many methods have been developed and are described in statistical literature ("How to Detect and Handle Outliers" by B. Iglewicz and D.C. Hoaglin, 1993, is a good starting reference). One of such methods is the boxplot rule which, in general form, defines the upper and lower fences as:

$$U = Q_3 + k(Q_3 - Q_1) \quad \text{and} \quad L = Q_1 - k(Q_3 - Q_1), \text{ respectively.}$$

Values falling outside the fences (also called the upper and lower cutoff points) are considered to be the potential outliers. In the above equations, Q_1 is the lower quartile, Q_3 is the upper quartile, $(Q_3 - Q_1)$ is the interquartile range, and the multiplicative constant k is one of the two factors determining the probability of labeling an observation as an outlier (the other factor is the number of observations). The common range for k is between 1.5 and 3.0. For the "standard" boxplot (the method recommended by the Ohio EPA) k equals 1.5. It is important to notice the distinction between results of the boxplot method when k takes a value on either side of this range. When k is set to 1.5, the boxplot may show a relatively high number of observations as outstanding, some of which may <u>not</u> be true outliers. On the other hand, when k equals 3.0, <u>all</u> observations that fall outside the cutoff points can be "safely" considered as outliers. A shortcoming, in this case, is that some lesser (but true) outliers may fall inside the fences and remain unflagged. In other words, the "standard" boxplot (k = 1.5) is more likely (approximately nine times - when a normally distributed data set consists of twelve observations) to label an observation as an outlier (albeit possible errors), than a boxplot where k equals 3.0. Hoaglin and Iglewicz (1987) have provided k values with specified probability of identifying at least one outlier in a normally distributed data set, depending on the number of observations. For example, if a data set consists of twelve observations, and k equals 2.2, the probability of labeling at least one observation as an outlier is 5%. The low probability of labeling an observation as an outlier also indicates that the test is "conservative" and that the labeled observation is indeed (very likely) an outlier. In cases where no detailed information exists about the origin of data, the above method can be advantageous by providing certain (predetermined) comfort level in screening out anomalous observations.

When screening observations for the purpose of creating a representative data set for determining background based remediation standards, a considerable amount of information on the data generating process is usually available. As required, the collection and analysis of soil samples is assumed to be a process controlled by some predetermined sampling methods, analytical procedures and sample handling protocols, where the good understanding of soils, contaminants and relevant site features provides the basis for the choice of sampling locations. Although the intent of all these requirements is to provide reliable information, it is quite possible that some anomalous observations could be made throughout the process. If these observations are judged exclusively by their numerical properties (through the use of a statistical test), there is danger that some of them could be removed from the data set, or retained within, without investigating into the causes for inconsistency. Since an outstanding observation may point to some important issue (like possible site wide contamination, inherent variability of soil, sampling problem, lab error, etc.), it is necessary to utilize all available information when deciding whether the observation will be (justifiably) discarded, or retained in the data set. For that reason, the Ohio EPA recommends a procedure in which the "standard" boxplot method (where k = 1.5) is used for labeling potential outliers in a background data set, followed by a thorough investigation to reveal the reasons for any discovered inconsistency.

The "standard" boxplot method is considered to be accurate when data are normally distributed. In other cases, it should be used with caution. For the heavily skewed distributions, other methods are available and described in statistical literature.

3.12.6 Remarks:

(1) It is frequently found that a BRS has been calculated in the log scale and then exponentiated back to the original scale. This procedure is generally not acceptable because the results of operations conducted on means and standard deviations of transformed data may be biased when directly transformed back into the original scale.

(2) In some cases, a BRS exclusively calculated in the log scale and then exponentiated back to the original scale can be used for the screening purpose - and only if it does not exceed 97.72nd percentile of the untransformed data set. To finally prove that the soil has been successfully remediated, a t-test should be conducted on the log transformed site and background data.

(3) Duplicate observations (resulting from duplicate soil samples) should not be averaged prior to a statistical evaluation. Such averaging could lead to spurious conclusions (for example, an outlier could be masked by a smaller value).

(4) When non-detects are present, the following statistical methods are recommended for data comparison:

Percent non-detects (ND)	Recommended Method
ND <= 15 %	Replace NDs with MDL/2 (half Method Detection Limit) and proceed with the following analysis: - For normally distributed data, use parametric statistics, i.e., *t* test or 95% Upper Confidence Limit test as outlined above. Remark: As an alternative to MDL/2, Cohen's method may be used (when data are normally distributed) to determine sample mean and variance (i.e., standard deviation) in order to proceed with a *t* test, or 95% Upper Confidence Limit test. - If data can not be normalized, use nonparametric statistics such as Wilcoxon Rank-Sum test.
15% < ND<= 50%	- For normally distributed data, use Cohen's method to determine sample mean and variance (i.e., standard deviation) in order to proceed with a *t* test, or 95% Upper Confidence Limit test. - If data can not be normalized, use nonparametric statistics such as Wilcoxon Rank-Sum test, or Test of Proportions.
50% < ND <= 90%	Use nonparametric methods only: - Wilcoxon Rank-Sum Test, or - Test of Proportions
ND> 90%	Use Poison Tolerance Limits, or establish BRS = MDL

(5) Beside the specially designed statistical computer programs, general spreadsheet software (Excel, LOTUS, etc...) can also be very useful in assisting the closure plan reviewers with statistical reviews. Most spreadsheet applications contain many "built-in" functions for calculating statistics like mean, quartiles (or percentiles), variance, standard deviation, etc. However, quartiles (as well as other statistics) calculated by spreadsheet software sometimes may not be the same as if they were determined through the procedures described in this guidance document. The discrepancy is usually caused by the difference in methods.

3.12.7 Statistical Analysis Step-by-Step Guidance

<u>Analyzing the Background Data Set (for the Constituent of Interest)</u>

Step 1: Number of observations

Does the background data set consist of a <u>minimum</u> of 12 (or more) observations derived from 12 (or more) background soil samples (not counting split samples and duplicates)?

NO - Find out the reasons for this deficiency and request additional soil samples in order to obtain a data set with at least 12 observations.

YES - Proceed with Step 2.

Step 2: Number of non-detects (values reported as below the <u>Method Detection Limit</u> - MDL)

Are there any non-detects in the background data set?

NO - Proceed with Step 3.

YES - Check if MDL has been clearly stated and remains the same for all soil samples.

If MDL is not clearly stated (or some other value - like PQL, i.e. Practical Quantification Limit, has been used), contact the facility and request the MDL (and any previously unreported values above the MDL) before proceeding with statistical analysis.

If several different values are reported as MDL, request that additional soil samples be analyzed as necessary to obtain a data set (12 observations minimum) based on the same MDL.

If MDL is clearly stated and remains the same for all soil samples, determine the percentage of non-detects.

If the number of non-detects is less than (or about) 15% of the number of observations in the data set, substitute the non-detects with MDL/2 (one half of the Method Detection Limit) and proceed with Step 3.

If the number of non-detects is more than 15% of the number of observations in the data set, proceed in accordance with recommendations given in Section 3.12.6, remark #4.

Step 3: Normality of the background data set distribution

In order to be used in a meaningful calculation of a background-based Remediation Standard (BRS), the values in a data set have to be normally distributed. To test the normality of a data set, several methods are recommended:

- Shapiro-Wilk (W) test
- Kolmogorov-Smirnov (KS) test with Lilliefors critical values
- Normal Probability plot
- Box and Whiskers plot.

The normality check should at least include the Normal Probability <u>and</u> Box and Whiskers plots, <u>and</u> either W or KS test.

If the values in the data set are normally distributed, proceed with Step 4.

If the values in the data set are <u>not</u> normally distributed, it may not be possible to calculate a meaningful "single number" as a BRS. In that case, determination on whether the soil has been successfully remediated will have to be based on a statistical comparison of the normalized (transformed) background and confirmation data sets.

Step 4: Test for outliers

Use the following equations (see examples in the previous Section "Test for Outliers") to determine whether there is statistical evidence that a background observation appears extreme and therefore does not fit the distribution of the rest of the data:

Upper cutoff = upper quartile + 1.5 (interquartile range) **Equation 1**

Lower cutoff = lower quartile - 1.5 (interquartile range) **Equation 2**

If there are no outliers, proceed with Step 5.

If outlier(s) is (are) found, resolve the outlier issues (as explained in Section 3.12.5.1) and proceed with Step 5.

Remark: If a data set has to be transformed to normality, test for outliers can be conducted prior to transformation (i.e., on the "raw" data), bearing in mind that the heavily skewed distributions require extra caution. Sometimes elimination of outliers (and substitution with other valid observations, as necessary) can, by itself, bring a data set to normality.

Step 5: Calculation BRS from a Normally Distributed Data Set

a) Calculate the mean (μ_b) and standard deviation (S_b) for the background data set.

b) Calculate BRS as:

$$BRS = \mu_b + 2\ S_b$$

If BRS was calculated from a <u>raw (untransformed)</u> background data set, it can be either used for direct comparison with the confirmation concentrations, or in a t test (where the raw confirmation data also has to be normally distributed).

If direct comparison between the BRS and the raw confirmation data shows that no confirmation concentration exceeds the BRS, **STOP HERE** - the soil has been successfully remediated for <u>this</u> constituent.

If direct comparison shows that one or more confirmation concentrations exceed the BRS, a thorough evaluation be conducted to determine if this presents a threat to humans and the environment, whether the elevated concentration(s) should be considered and addressed as "hot spot(s)", whether and how many additional soil samples need to be collected, is it appropriate to perform ("switch" to) a statistical comparison, should these values be included in the data set when conducting a statistical test, etc.

If BRS was calculated from a <u>transformed (normalized)</u> background data set, it can <u>only</u> be used for a statistical comparison (where the confirmation data also has to be normalized with the same transformation.

Proceed with analysis of the confirmation data set.

<u>Analyzing the Confirmation Data Set (for the Constituent of Interest)</u>

Step 1: Number of observations

Does the confirmation data set consist of at least 12 observations derived from an equal number of confirmation soil samples (not counting split samples and duplicates)?

NO - Find out the reasons for this deficiency and request additional soil samples in order to obtain a data set with a minimum of 12 observations. (In some cases, where only direct comparison with BRS is employed, a smaller number of confirmation samples may be sufficient.)

YES - Proceed with Step 2.

Step 2: Number of non-detects (values reported as below the <u>Method Detection Limit</u> - MDL)

Are there any non-detects in the confirmation data set?

NO - Proceed with Step 3.

YES - Check if MDL has been clearly stated and remains the same for all soil samples.

If MDL is not clearly stated (or some other value - like PQL, i.e. Practical Quantification Limit, has been used), contact the facility and request the MDL (and any previously unreported values above the MDL) before proceeding with statistical analysis.

If several different values are reported as MDL, request that additional soil samples be analyzed as necessary to obtain a data set (12 observations minimum) based on the same MDL.

If MDL is clearly stated and remains the same for all soil samples, determine the percentage of non-detects.

If the number of non-detects is less than (or about) 15% of the number of observations in the data set, substitute the non-detects with MDL/2 (one half of the Method Detection Limit) and proceed with Step 3.

If the number of non-detects is more than 15% of the number of observations in the data set, proceed in accordance with recommendations given in the previous Section 3.12.6, Remark #4.

Step 3: Normality of the confirmation data set distribution

In order to be compared with BRS (through a t test), the values in the confirmation data set have to be normally distributed. To test for normality of the confirmation data set, the same methods (previously recommended for the background data set) can be used.

If the values in the confirmation data set are normally distributed, <u>and</u> the values in the background data set are normally distributed, proceed with the t test.

If the values in the confirmation data set are <u>not</u> normally distributed, a logarithmic or some other transformation should be performed <u>on both data sets</u> (confirmation <u>and</u> background) in attempt to normalize them.

If both data sets can be normalized with the same transformation, proceed with the t test.

If the attempt to normalize data fails, nonparametric statistical methods (such as Wilcoxon Rank-Sum test, or Test of Proportions) must be used in order to determine if the soil has been successfully remediated.

<u>t Test</u>

For convenience, t test will be explained through the following example:

Given the background and confirmation data (in mg/kg) for barium,

Ba - Background	Ba - Confirmation
3.43	15.7
43.37	37.5
44.51	43.7
45.04	44.63
48.29	45.88
50.81	49.5
57.74	55.84
62.36	60.71
64.76	70.26
78.27	80.62
79.4	110.3
110.8	115.24

the mean and standard deviation for the background data set are:

$$\mu_b = 57.398 \text{ and } S_b = 25.946$$

and the BRS can be calculated as:

$$BRS = \mu_b + 2\ S_b$$

$$\text{or } BRS = 57.398 + (2 \times 25.946) = 109.29 \text{ mg/kg.}$$

In order for the soil to be declared remediated for barium, a t test must show that the 95% upper confidence limit for the mean of confirmation data is smaller than the BRS, i.e.:

$$\bar{Y} + t_{m-1,\ 0.95} \times (S_y/\sqrt{m}) < BRS$$

where:

- $\bar{Y}$ - mean of the confirmation data,
- $t_{m-1,\ 0.95}$ - t-distribution critical value for m-1 degrees of freedom (df) and confidence level of 95%,
- S_y - standard deviation of the confirmation data, and
- m - number of confirmation data points (observations).

From the confirmation data set:

$$m = 12$$
$$df = m-1 = 11$$
$$\overline{Y} = 60.823$$
$$S_Y = 29.236$$

From the table below:

$$t_{m-1,\,0.95} = 1.796$$

t distribution critical values for 95% confidence level

df	4	5	6	7	8	9	10	[redacted]	12
t crt. val.	2.131846	2.015049	1.943181	1.894578	1.859548	1.833114	1.812462	[redacted]	1.782287

df	13	14	15	16	17	18	19	20	21
t crt. val.	1.770932	1.761309	1.753051	1.745884	1.739606	1.734063	1.729131	1.724718	1.720744

df	22	23	24	25	26	27	28	29	30
t crt. val.	1.717144	1.71387	1.710882	1.70814	1.705616	1.703288	1.70113	1.699127	1.69726

Remark: t distribution tables with critical values for other confidence levels and degrees of freedom can be found in various books on statistics.

By entering the values in the t test expression (where the left side represents the upper 95% confidence level for the mean of the confirmation data, and the right side is the BRS),

$$60.823 + 1.796\ x\ (29.236\ /\ \sqrt{12}) < 109.29, \quad \textit{i.e.:}$$

$$75.98 < 109.29$$

it can be shown that the 95% confidence level for the mean of the confirmation data does not exceed the BRS, and the soil can be declared remediated for barium.

Another way to conduct this test is to calculate a t value using confirmation and background data, and then compare it to an appropriate critical value, i.e.:

$$\frac{\overline{Y} - BRS}{S_y / \sqrt{m}} < -t_{m-1,\ 0.95}$$

$$\frac{60.823 - 109.29}{29.236 / \sqrt{12}} < -1.796$$

$$-5.743 < -1.796$$

It is interesting to note that (in this example) the soil can be declared remediated for barium, in spite of the fact that the two confirmation soil samples exhibit concentrations above the BRS.

3.12.8 References

American Society for Testing and Materials, 1997. *Standard Practice for Dealing with Outlying Observations*, ASTM E178-94. American Society for Testing and Materials, West Conshohocken, Pennsylvania.

Bickel, P. J., and K. A. Doksum, 1977. *Mathematical Statistics: Basic Ideas and Selected Topics*, John Wiley & Sons Inc., New York, New York.

Conover, W. J., 1980. *Practical Nonparametric Statistics*, 2nd ed., John Wiley & Sons Inc., New York, New York.

Devore, J., and R. Peck, 1986. *Statistics: The Exploration and Analysis of Data*, West Publishing Company, St. Paul, Minnesota.

Gilbert, R. O., 1987. *Statistical Methods for Environmental Pollution Monitoring*, Van Nostrand Reinhold, New York, New York.

Hoaglin, D. C., F. Mosteller, and J. W. Tukey, 1983. *Understanding Robust and Exploratory Data Analysis*, John Wiley & Sons Inc., New York, New York.

Iglewicz B., and D. C. Hoaglin, 1993. *How to Detect and Handle Outliers*, American Society for Quality Control, Statistics Division, Milwaukee, Wisconsin.

Shapiro S. S., 1990. *How to Test Normality and Other Distributional Assumptions,* American Society for Quality Control, Statistics Division, Milwaukee, Wisconsin.

Snedecor G. W., and W. G. Cochran, 1980. *Statistical Methods,* 7th ed. Iowa State University Press, Ames, Iowa.

U.S. Environmental Protection Agency, 1992. *Statistical Analysis of Ground-Water Monitoring Data at RCRA Facilities, Addendum to Interim Final Guidance*, Office of Solid Waste, U.S. Environmental Protection Agency, Washington, D.C.

U.S. Environmental Protection Agency, 1992. *Statistical Training Course for Ground-Water Monitoring Data Analysis*, EPA/530-R-93-003. Office of Solid Waste, U.S. Environmental Protection Agency, Washington, D.C.

U.S. Environmental Protection Agency, 1997. *Test Methods for Evaluating Solid Waste, Physical/Chemical Methods, SW-846*, 3rd ed., Final Update 3. Office of Solid Waste, U.S. Environmental Protection Agency, Washington, D.C.